MODELLING OF SUITABLE AREAS FOR ESTABLISHING GRAZING RESERVES AND STOCK ROUTES IN ZURU EMIRATE, KEBBI STATE, NIGERIA

BY

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BY

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(P19EVGM8008)

A THESIS SUBMITTED TO THE SCHOOL OF POSTGRADUATE STUDIES, AHMADU BELLO UNIVERSITY, ZARIA, IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE AWARD OF MASTER OF SCIENCE (MSc.) DEGREE IN GEOMATICS

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SEPTEMBER, 2024

DECLARATION

I hereby declare that the work contained in this thesis titled "Modelling of Suitable Areas for Establishing Grazing Reserves and Stock Routes in Zuru Emirate, Kebbi State, Nigeria", has been sourced, researched, carried out, compiled and written by me in the Department of Geomatics, Ahmadu Bello University, Zaria. The information derived from the literature has been duly acknowledged in the text and list of reference provided. To the best of my knowledge, no part of this project thesis was previously presented for another degree or diploma at this or any other institution.

______________________________ ______________________

MALEEKS, YA'U ADAMU DATE

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CERTIFICATION

This is to certify that this dissertation titled "MODELLING OF SUITABLE AREAS FOR ESTABLISHING GRAZING RESERVES AND STOCK ROUTES IN ZURU EMIRATE, KEBBI STATE, NIGERIA." by MALEEKS, Ya'u Adamu meets the regulation governing the award of Masters of Science (MSc.) degree in Geomatics of the Ahmadu Bello University, Zaria and is approved for its contribution to knowledge and literary presentation.

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(Dean, School of Postgraduate Studies) ____________________ SIGNATURE ______________ DATE

DEDICATION

This work is dedicated to my late Parents (may God grant them eternal rest), and the entire family of Iyan Rafin Zuru.

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Firstly, I give all glory and adoration to God Almighty for He is worthy of my praises.

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ABSTRACT

Recent occurrences in Zuru Emirate have revealed that the struggle for common resources (land) is one of the factors that has resulted into violent conflicts in the area between Fulani herders and local crop farmers. With increasing urbanisation and land use and land cover changes, the identification of adequate and suitable grazing areas is becoming crucial to ensuring the survival of pastoral communities. This research used geospatial techniques and multicriteria decision analysis tools to model suitable areas for siting grazing reserves in Zuru Emirate, Kebbi State. The eleven criteria used to conduct the land suitability analysis for the grazing reserve in Zuru Emirate are land use, land cover, slope, temperature, precipitation, elevation, distance from water, distance from road, distance from settlement, soil organic carbon, soil pH, and soil depth. All the criteria were standardised and weighted using the Analytical Hierarchy Process AHP in order to produce a land suitability map for the grazing reserve. To assess the reliability of the land suitability map, zonal statistical analysis was used to calculate the mean Normalized Difference Vegetation Index NDVI value of each land suitability class. The results of the AHP weighted analysis of the criteria revealed that land use was the most influential criterion with a weight of 0.22 (22%), while soil depth and soil pH had the lowest weight of 0.04 (4%). The results of land suitability mapping for grazing reserves indicated that 0.92% of the study area is least suitable, 83.13% is moderately suitable, 16.48% is suitable, and only 0.46% of the study area is most suitable for siting grazing reserves. This may fit into determining the reliability of a suitability map for vegetation or crop areas. It is recommended that consistent monitoring and revisions of the land suitability map be conducted to allow decision-makers to make informed decisions about sustainable land use planning and management.

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LIST OF ACRONYMS

AHP:	Analytical Hierarchy Process
CPWCM:	Criteria Pair-Wise Comparison Matrix
CR:	Consistency Ratio
FAO:	Food and Agricultural Organization
GIS:	Geographic Information Systems
GSARS:	Global Strategy to improve Agricultural and Rural Statistics
LGA:	Local Government Area
LULC:	Land Use and Land Cover
MCA:	Multi-Criteria Analysis
MCDM:	Multi-Criteria Decision-Making
MCE:	Multi-Criteria Evaluation
NDVI:	Normalized Difference Vegetation Index
NPC:	National Population Commission
PCM:	Pair-Wise Comparison Matrix
pH:	Soil Reaction
RS:	Remote Sensing
ZSB:	Zuru Schist Belt

CHAPTER ONE

INTRODUCTION

1.1 Background to the Study

Pastoralism is facing global crisis due to man-made activities, natural constraints, internal and external influences (Martin, *et al.*, 2020; Wang et al., 2020). The expansion of human settlements in both developed and developing countries in the 21st century has led to the depletion of land resources. (Ajibo *et al.* 2018; Nhim, *et al.*, 2019; Depauw *et al.*, 2019). The high demand for pastoral facilities like grazing reserves has led to ongoing conflicts and disputes, resulting in the loss of lives and properties (Berry, 2018; Mahdi, 2018; Furini, 2019).

The relationship between Fulani herders and multi-communal settled farmers has significantly deteriorated over centuries(Goke, 2018; European Asylum Support EASO, 2021). Amnesty International (2018) cited that,"past issues related to cattle grazing on farmlands have been resolved amicably". with occasional conflicts managed by the people or village heads(Mrabure and Awhefeada, 2020). Despite this, the harmonious relationship between these communities has remained a topic of discussion.

The Sahel regions of Nigeria are experiencing increased withering of pasture, leading herdsmen to seek pasture and water in sub-humid zones. This process, is described as "transhumance" by the United Nations Office for West Africa and the Sahel (UNOWAS) (2018), involves a longer rainy season and grassland with moderate temperatures and longer soil retention. This encroaching on farmlands, displacing farmers who retaliate, is a significant issue in the region.Nnoko (2018) explains that increasing aridity in Nigeria's Sahel and Northern regions, exacerbated by desertification and increased risk of extreme weather events, has led to an increase in farmer-herder conflicts.This is said to have resulted in a decrease in the availability of grazing land, as well as the movement of pastoral herds Southward into the humid and sub-humid zones (Feldt *et al.,* 2020).According to Samuel *et al.,* (2020), the activities of the pastoralist include the movement of their cattle to graze on farmlands which belong to crop farmers, while the farmers require manure to fertilize their agricultural land. the survival of the pastoralist group is formed under interaction with the sedentary farmers. Thus, it has become apparent that the interdependent linkage flows as each group needs water, land, fodder and other land use for their economic activities.

The decrease in grazing land availability and the movement of pastoral herds into humid and sub-humid zones has led to interdependent linkages between pastoralists and sedentary farmers(Feldt *et al.,* 2020). The pastoralists move their cattle to graze on farmlands owned by crop farmers, while farmers require manure for fertilization(Samuel *et al.,* 2020).Similarly, Monod (2018) noted that “the survival of the pastoralist group is formed through interaction with sedentary farmers, highlighting the interdependence of water, land, fodder, and other land use for economic activities”, thus, it has become apparent that the independent linkage flows as each group needs water, land, fodder and other land use for their economic activities. Unfortunately, this form of relationship that has existed centuries back has been truncated due to the struggle over land, with many disputes arising across the regions that have grown into widespread death and internal displacement of persons (Edward, 2022).

According to Cécile *et al.* (2018), site suitability considers the appropriateness of livestock grazing for a particular land area, based on the economic, social and environmental considerations that may be affected by livestock grazing. Land suitability modelling aids in determining the most suitable spatial pattern for future land use based on specific requirements, preferences, and activity predictors (biophysical and environmental criteria such as water, road, settlement, soil organic carbon, soil pH and soil depth), crucial for locational and siting decisions. (Collins *et al.,* 2001; Obsa, 2021).

Grazing reserves are established to protect lands from crop farming, facilitate pastoralist access, and promote sedenterization of nomadic/transhumant pastoralists through legally secured titles to grazing, ultimately promoting livestock development(Ele, 2020).

Strong social networks exist between herders, local cattle dealers, politicians, and landowners in Nigeria. However, their migration routes and grazing zones are not protected, leading to frequent clashes over land allotment. The violence is primarily caused by herders' increasing demand for grazing pastures and farmers' attempts to keep herdsmen out of their fields(Bukari *et al.,* 2018).Conflicts between farmers and herdsmen have led to physical damage, injuries, and family deaths, as well as socio-psychological effects like emotional exhaustion, job dissatisfaction, income loss, and decreased resources and yield(Adebo and Olotu, 2018;Adeniyi *et al.*, 2020).

Land suitability classification evaluates specific land areas based on crop requirements and soil/land characteristics, determining their suitability for a defined use. Suitability is also a measure of how well the qualities of a land unit match the requirements of a particular form of land use (Aymen *et al.*, 2021).

Allison (2021) highlights “the Nigerian governments’ demand for grazing reserves and stock routes, are crucial for pastoralists and their livestock”. Establishing these sites at comfortable locations is essential, especially in conflict-ridden areas in Zuru Emirate. Modelling suitable grazing reserves and stock routes can boost livestock populations, reduce herding difficulties, and enhance symbiotic interactions among farmers, pastoralists, and rural dwellers. Multicriteria Criteria Decision Analysis (MCDA) techniques in GIS environments can help identify suitable sites, considering biophysical, socio-economic, and environmental factors.

The research utilized geospatial techniques, specifically Multi Criteria Decision Analysis (MCDA) or Multi Criteria Evaluation (MCE) in a GIS environment, to identify suitable areas for grazing reserves within the study area(Sisman and Aydinoglu, 2020). The MCDA offers various techniques for decision problem structuring, design, evaluation, and prioritization. GIS-based MCDA combines geographical data and decision-makers' preferences to obtain information for decision making, transforming and enhancing decision-making processes. (Tahri *et al.*, 2021).

1.2 Statement of the Research Problem

A large proportion of Nigerians, ranging from fifty to eighty percent, are involved in either crop or livestock farming, which are both vital aspects of their daily lives. The agricultural sector in Nigeria is constantly evolving, with farmers who were traditionally involved only in crop production now embracing crop-livestock farming as well (Akinola *et al*., 2015).The incessant occurrence of different types of conflicts (political, religion, environmental, ethnic, resource, and so on) is not an alien phenomenon to Nigeria and the West African region at large. There has been an increasing number of conflicts in Nigeria over recent times, arising from the activities of the nomads which is linked to the farmer-herder conflict (Egbuta, 2018; Oli *et al.*, 2018).Chukwuemeka *et al*., (2018) emphasized the critical role played by livestock in increasing food and nutrition availability, providing raw materials for industries, and contributing to the agricultural revolution.

Zuru Emirate comprises an agrarian community like other places in Nigeria with majority of its population engaged in either crop cultivation or livestock farming such as cows, sheep and goats that require vast expanse of open land for grazing (Gaddafi *et al.*, 2021). Recent occurrences in Zuru Emirate have revealed that, struggle for common resources is one of the factors that have degenerated into violent conflicts in the area between Fulani herders and local crop farmers (Sanchi *et al.*, 2021). In addition, the encroachments of traditional cattle routes and grazing reserves as a result of increased population have drastically reduced the grazing space for the livestock to access pasture and water points. This has triggered crisis between the Fulani herders and crop farmers (Ibrahim *et al.*, 2017). It was also observed that, most of the livestock found within the study area and its environs are kept under traditional method of livestock practice (transhumance) which demands free movement of livestock from one point to another in search of pasture (Mahdi, 2018).

Dale (2018) opined that there can be no solution to the intractable strife between pastoralists and farmers so long as the problems of grazing land use are not addressed. The issue of settling nomadic cattle breeders is a problem which for many years now has generated considerable discussion in Nigeria's public and government circles (Apeh *et al.*, 2021). Beetseh (2018) put forward the suggestion that ranching is the most effective method of cattle rearing for tackling the fundamental issues behind the herders and farmers crisis in Nigeria, while also ensuring the sustainability of the land and the livelihoods of local communities.

It is clear that the issue of livestock rearing in Nigeria is intertwined with broader issues of sustainable development, and requires coordinated efforts to address the challenges faced by local communities and ensure the long-term viability of the land. Ultimately, if we are to build a sustainable future for Nigeria, we must take a holistic approach that considers the interdependencies between agriculture, environment, and society (Chukwuemeka *et al.*, 2018).

In order to achieve the goals of sustainable development, the evaluation of land suitability as a major study in the land use planning is an essential step for the development process to be tailored to the environmental capabilities of each area (Noraei *et al*., 2015).With increasing urbanization and landuse land cover changes, the identification of adequate and suitable grazing areas is becoming crucial to ensure the survival of pastoral communities. Therefore, there is a pressing need to investigate the land suitability for siting grazing reserves in Zuru Emirate in order to develop sustainable methods of managing livestock.

Many researchers have used multicriteria decision analysis techniques such as analytical hierarchy process (AHP) to conduct land suitability for siting grazing reserve (Samuel *et al*., 2020; Tashayo *et al.*, 2020; Zumo *et al.*, 2020) with positive results. Unfortunately, most of these studies failed to incorporate soil properties such as pH, organic carbon, and soil depth in land suitability analysis.

Therefore, this research employedmulticriteria analysis to identify suitable locations for establishing grazing reserves in Zuru Emirate, Kebbi State, Nigeria. This involved taking into account various factors such as climate, socio-economic conditions, soil characteristics, and topography, with the ultimate goal of promoting sustainable livestock grazing practices, reducing environmental damage, and meeting the needs of the surrounding communities.

1.3 Research Questions

This research provides answers to the following research questions;

i. What are the various Land Use and Land Cover in the study area?

ii. What are the criteria required for locating grazing reserves in the study area?

iii. Where are the appropriate locations to site grazing reserves in the study area for optimum performance and comfort for pastoralists?

iv. What is the reliability of the suitability map for siting grazing reserves in the study area?

1.4 Aim and Objectives

1.4.1 Aim of the study

The aim of this study is to model suitable areas for siting grazing reserves and stock route in Zuru Emirate using GIS-based Multi Criteria Decision Analysis, with the view of making informed decisions in land planning and management in order to reduce farmer-herders' conflicts across the country.

1.4.2 The objectives of this research workareto:

i. identify and map the Land Use and Land Cover within the study area

ii. examine the criteria for siting grazing reserve in the study area

iii. model suitable areas for siting grazing reserve in the study area.

iv. determine the reliability of the land suitability map for siting grazing reserve in the study area.

1.5 Justification of the Study

There is no doubt that satisfactory sites for grazing reserves in Zuru Emirate needs to be modelled and established. Technological advances within the field of Geographic Information Sciences (GIS), Remote Sensing (RS), and Global Positioning Systems

(GPS) assist with the siting of grazing reserves by looking at grazing patterns and stock routes since 2000(Jayakumar, 2019). GIS provides an environment where pertinent variables can be analysed on a smaller and more manageable scale.

Siting suitable areas for the grazing reserve in Zuru emirate using remote sensing technology and GIS will be a critical step towards understanding the complex, interaction between the biological and socio-economic components of the landscape and will go a long way in curbing the various ills experienced between nomads and farmers.

Selecting suitable sites for grazing reserves are geographic in nature and hence coupling GIS with MCDA is impactful. Spatial problems typically will involve a large set of feasible alternatives and multiple, conflicting and incommensurate evaluation criteria (Ustaoglu, *et al.,* 2021). GIS-MCDA has proven to be a technique that can quantitatively assess, evaluate, transform and combine geographical data and value judgments to solve spatial problems that are associated with determining appropriate locations for infrastructure development. To do this, it considers geographical data models, the spatial dimension of the evaluation criteria and decision alternatives in evaluating the criteria (Paul *et al.,*2020).

Many of the complicated unrests faced between herders and farmers within the study area are due to lack of grazing reserves and stock routes. However, the need to suitably establish this reserves and compromise to find a solution in Zuru emirate is inevitable. Therefore, the benefits of this research are poised at the settlement of 'nomadic' pastoralists; it would offer security of tenure as an inducement to sedenterization through the provision of land for grazing and permanent water. Large pieces of land will be demarcated legally, sanctioned by order in the Official Gazette and infrastructure, such as dams, veterinary clinics and boreholes will be constructed. Potential settlers will be recruited through the livestock extension service (Chukwuemeka *et al.,* 2018).

This study is justified in the sense that, with the problems noted as regards to the various conflicts that have ensued between herdsmen and farmers across the country which arose from the destruction of farm lands by herds of cattle, and with the government's willingness and strategies to curb these problems, there is a strong need for pastoralists to be given rights to land furnished with basic amenities for the settlement of their herds and their families (Namgay*et al.,* 2021). Akomolafe (2015) opined that "the development of grazing reserves and livestock routes has become imperative to avoid conflicts between pastoralists and farmers".

Suitability mapping using Multicriteria Analysis (MCA) in GIS can solve the intractable problem of frequent farmer-herders clashes by helping to locate appropriate sites where nomads can be settled all year round; far away from agricultural lands and human settlements, therebyimprovingfood security and the security of lives and property. Moreover, the settlement of the nomads would boost livestock production and promote sustainable agriculture. This study will go a long way in positively impacting the socio-economic development in the study area due to transactions of livestock products (Gil*et al.,* 2019). An added advantage academically is that this study can serve as a benchmark or a model which can be improved upon for selecting suitable sites using GIS-based MCDA for grazing reserves in Kebbi State and other States in Nigeria.

1.6 Scope and De-limitation of the Study

This study has focused on Zuru emirate.Though it is pertinent that other local governments in Kebbi State should be considered as well, but this can be in subsequent studies linked to this research. The study area was selected because of the availability of data. The study did not go outside the context of establishing grazing reserves. In this research, GIS was used to suggest new locations for siting grazing reserves in Zuru Emirate, Kebbi State.

Based on specifications and recommendations for a detailed analysis for specific suitability, the study involved the use of biophysical, socioeconomic and environmental datasets or variablesincluding water, road, settlement, soil organic carbon, soil pH and soil depth. Furthermore, the multicriteria analysis carried out in this research made use of data majorly from year 2021 and is within a time frame of 12 months for both dry and rainy sessions- from data collection, processing, analysis to the submission of final report.

1.7 TheStudy Area

1.7.1 Geographical location

The area of study is Zuru Emirate.Zuru Emirate is located in the southern part of Kebbi State Nigeria. It lies between Latitudes 10°01'14" and 11°01'14"North of the Equator and Longitudes 04°01'14" and 06°00'00"East of the Central Meridian. It occupies a total land mass of about 9,000 sq.km. The headquarters of Zuru Emirate is in the town of Zuru which comprises of four Local Government Areas (LGA), namely: Danko/Wasagu, Fakai, Sakaba and Zuru. The emirate is divided into five administrative Chiefdoms headed by Third class Chiefs namely: Dabai, Danko, Fakai, Sakaba, and Wasagu (Zaka, 2018). It is bordered by Bukkuyum Local Government in Zamfara State in the North, while in the East it shares boarder with Kuyanbana in Kaduna State.To the South of the study area is Niger State of which the borderline extends also arbitrarily on land in the West to a point where it ends a few kilometres to the large tributary of Dan

Zari River, a Northwest ward protrusion of Yauri and Gwandu Emirates of Kebbi State(Alhassan, 2019).

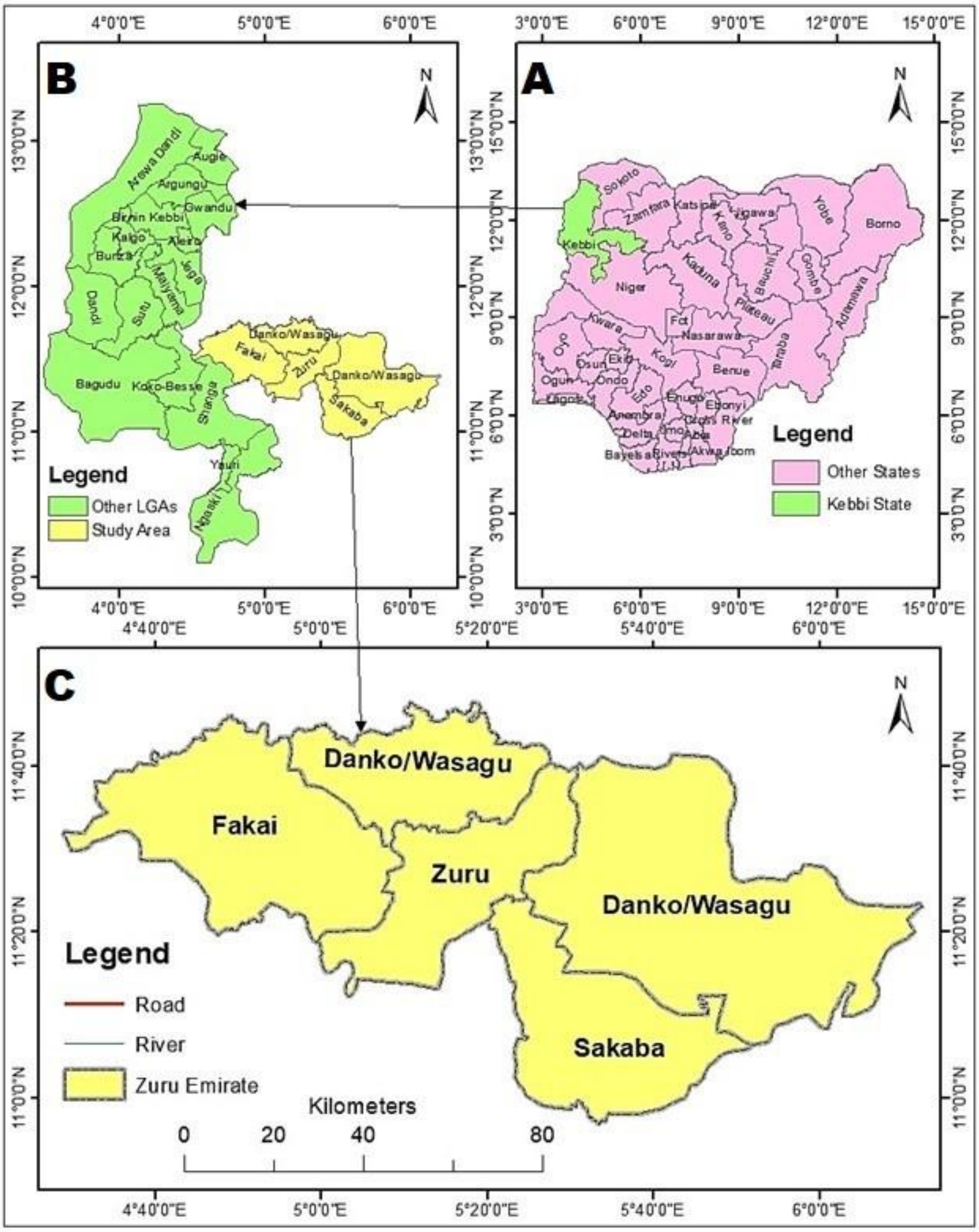

Figure 1.1 Map of Zuru Emirate

(A) indicates the map of Nigeria and its States,
(B) the administrative boundary of Zuru Emirate within the border of Kebbi state,
(C) administrative boundary of Zuru Chiefdoms.

1.7.2 Climate

The climate of Zuru Emirate is typical to that of a tropical continental type weather condition marked by a dry and wet season. It experiences a period of Harmattan from the months of December to February. The average rainfall is about 1825mm with a mean temperature of 27°C. The wet season is from April to October. Night temperatures are generally lower. Relative humidity is generally low (40 percent) for most of the year except during the wet season when it reaches an average of eighty percent (Maleeks *et al.*, 2021).

1.7.3 Vegetation

The study area lies on the plains of Northern Nigeria and its topography is undulating with a height above Mean Sea Level (MSL) of about 350 to 1000m. Zuru emirate has a savannah kind of vegetation which is transitionally in-between Northern Guinea Savannah and Sudan savannah with pockets of woodland vegetation along river basins and is covered by more or less continuous grass cover, but in some parts, tree growth suppresses the grass growth. Zuru has a favourable climatic condition for growing many crops (Agan *et al.*, 2019).

1.7.4 Geology

The Zuru Schist Belt (ZSB) is the most westerly schistbelt in the Nigerian basement. It is mainly sedimentary, with some weathered basement complex rock outcrops in the south (Emujakporue*et al.*, 2018).The mainrock types are medium-grained granite, quartz-micaschist, and quartzite while minor ones are quartz vein, quartzofpegmatite and aplitic dyke (Kitha *et al*. 2021). Zuru Emirate is boarded with highlands traversing the Western side for a substantial distance and in the East is relatively flat with doted isolated Granites and layers of hills.

1.7.5 Soil

Zuru emirate is a well-drained, sedimentary region with cultivatable lands in the lower and southern regions. Its moderately deep, sandy and loamy soils are widely distributed, providing food and feed to farmers and herders (Agan *et al.,* 2019).

1.7.6 Socio-economic activities

Animal rearing is carried out in conjunction with crop cultivation on a small scale in the area. The inhabitants of Zuru Emirate are predominantly reliant on the Fulani pastoralists for their supply of meat, milk, and butter. Hunting is a crucial commercial pursuit that comes after crop farming and acts as a supplementary source of meat, as well as hides and skins for the production of shoes, battle attire, and indigenous musical instruments. Apart from animal husbandry and hunting, the women engage in pottery and weaving, while the men specialise in blacksmithing activities. These trades contribute significantly to the overall economic development of the community, aside from crop cultivation and livestock management(Sanchi *et al.,* 2022). In fact, going by history, Zuru people being multi-ethnic are grouped into categories. First category is of those that claim long term settlement 'Lelna' and the second category is of the much more recent settlers who in fact regard themselves – and are also regarded by the others as recent immigrants or even as temporary strangers. In the first category are the Achifawa, Kambari, Dukkawa Fakkawa,'Dankawa, Worawa, Katsinawa (Zaka, 2018).

1.7.7 Population

Zuru Emirate has an estimated population of about 1,011,309 (National Bureau of Statistics, 2019).The geographical area is home to a diverse array of ethnic populations, including but not limited to Dakkarkari, Fakkawa, Dukkawa, Kelawa, Kambarawa, Katsinawan Laka, and Achifawa. In addition to these, the area is also home to settlers from other ethnic groups, including Hausa, Fulani, Yoruba, Igbo, and so on. As far as religions are concerned, the area is characterised by the presence of Islam, Christianity, and traditionalist practises. Despite the dominance of these mainstream religions, the traditional worship of various deities is still prevalent in the region, with numerous festivals being celebrated throughout the year. These festivals provide an opportunity for the locals to uphold their traditional beliefs and customs and express their cultural identity. The region is a convergence of varied ethnic groups and religious beliefs, creating a distinctive and captivating destination that is worth exploring. (Sanchi *et al*., 2022).Figure 1.1 shows the inset map of Zuru Emirate with all the LGAs that makes up the Emirate.

CHAPTER TWO
LITERATURE REVIEW

2.1 Conceptual Framework

The conceptual framework hinges on the general concept of grazing reserve and analysis of land suitability for establishing grazing reserve.

2.1.1 The concept of grazing reserves

Grazing reserves are essentially areas of land that have been bought, developed, and released to pastoralists (Iro, 2013). According to Okaiyeto and Muhammad (1997), grazing reserves are areas of land set aside specifically for the settlement and technical support of herdsmen. However, the predicted carrying capacity of grazing reserves based on stocking density decreases from arid to humid zones in accordance with rainfall patterns and growing season length(Dahiru*et al.*, 2019).

Grazing land/rangeland is a semi-natural, uncultivated environment used by wildlife and animals for extensive grazing or browsing. Grazing land/rangeland encompasses over half of the world's ice-free land surface, or 74 million km^2 (Sayre *et al.*, 2017). They comprise savannah, grassland, steppe, tundra, shrubland, desert, and forest biomes (Sayre *et al.*, 2017). Carbon sequestration, nutrient recycling, water catchment, wildlife habitats, and biodiversity conservation are all provided by rangelands (Bailey *et al.*, 2019; Olsson *et al.*, 2019; Reda *et al.*, 2020). They also help to fulfil numerous United Nations Sustainable Development Goals (SDGs), including poverty reduction, food security, climate action, and land life (Espeland *et al.*, 2020).

Grazing land/rangeland provide a living for more than 2.5 billion people worldwide (Engler and von Wehrden, 2018).Through the provision of grazing resources for livestock production, edible food products (honey, mushrooms, wild fruits, game meat, etc.), non-timber forest products, recreational activities (for example, tourism), and a variety of other direct and indirect benefits (Kazungu *et al.*, 2020).Because crop production has limited promise in these places, livestock grazing is critical in utilizing dry rangelands for food production (Treydte *et al.*, 2017). Rangelands are estimated to be responsible for roughly 50% of world livestock output, supporting 600 million rural households (Briske *et al.*, 2020). In comparison to the year 2000, continuous population expansion in Sub-Saharan Africa (SSA) is predicted to raise food demand by 55 percent by 2030. (Godde *et al.*, 2018). This, together with expected increases in household purchasing power, means that livestock goods will have a ready market as more households can afford animal-source protein in their diet (Philipsson *et al.*, 2011).However, livestock production in SSA is currently underperforming due to issues with graze land productivity, such as seasonal changes in fodder growth and a decrease in available grazing land (Treydte *et al.*, 2017; Godde *et al.*, 2018).

Due to existing land reallocation for other uses, such as crop production, conservation, and settlement expansion, the amount of grazing land/rangeland available for cattle grazing is decreasing (Kilawe *et al.*, 2018; Kazungu *et al.*, 2020). As a result of overgrazing, grazing land reallocation puts a load on the remaining grazed resources and reduces grazing land sustainability and production (Pfeiffer *et al.*, 2019). Food security and livelihoods among extensive livestock keepers on open grazing land in SSA have been threatened by poor grazing land productivity due to overgrazing and continued climate change effects. Traditional livestock keepers have been seeking new grazing pastures as a result of these reasons, as well as rising demand for animal-source foods due to population and economic growth (Philipsson *et al.*, 2011).

2.1.2 Concept of land suitability

The separation of land into varying components is dependent on its ability to tackle/resolve specific tasks. This procedure is known as land suitability analysis. Land suitability analysis can be categorised as low and high. Low land suitability analysis is described as small component parts required for specific use or purpose. The high land suitability analysis implies that the land requires a large number of component parts to serve a specific use or purpose (Joseph, 2006). Each part of the Earth's landscape has its unique characteristics that makes it better suited to certain uses than others.

The skills, and experiences available to people, influence how they use the land. The evaluation of land suitability is similar to the selection of a suitable site, except that the goal is to map the suitability index for the entire study area rather than to isolate the best alternatives. To assess land suitability for development, Senes and Toccolini (1998) combined the UET (Ultimate Environmental Threshold) method with map overlays. Hall *et al.* (1992) cited in Malczewski (2006), used map overlays to define homogeneous zones and then utilised classification techniques to assess each zones' agricultural land suitability level. Combining GIS and MCDA to assess land suitability is also a powerful approach (Florent *et al.*, 2001). The suitability of land can be determined primarily by its quality. Land quality is a complex feature of land that has a direct impact on land use (FAO, 1993). Soil texture, drainage, PH, topography, and climatic factors are some of these characteristics. The interaction of several land characteristics, which are measurable attributes of the land, determines the majority of land qualities. The role of land quality in evaluating and grouping land types according to their fitness of orders and groups is critical. 'N' denotes land qualities that do not allow the form of use considered or are not suitable for appropriate results, whereas 'S' denotes lands that are ideal for use with good advantages (FAO, 1985, as cited in Melku, 2021).

The future biological productivity of land determines its suitability (FAO, 1985). Environmental factors such as temperature, local topography (roughness, steepness, and exposure), soil type, and existing vegetation can all influence land productivity. Different factors of land characteristics are taken into account when creating a land suitability classification. Different factors of land characteristics are usually taken into account when creating a land suitability classification. The classification of the land's suitability is determined by considering a variety of factors related to the land's characteristics. A weighted value ranging from 1 (inappropriate) to 5 (most suitable) is assigned to each land use based on its suitability. For each land use, the weighted value of each factor was reclassified. Each parameter is assigned a value based on how well it fits into each land use category. To determine the suitability of land for each land use type, the weighted value of each land characteristic factor is added together and the average value is taken. The final suitability for each land use is determined by categorizing the average value of them into five appropriate classes (Melku, 2021).

2.2 Theoretical Framework

The theoretical framework hinges on evaluation of grazing reserves in Nigeria, GIS for site suitability analysis for grazing reserve and factors that influence site suitability for grazing reserve.

2.2.1 Evolution of grazing reserves in Nigeria

In the 1960s, the Nigerian government focused its policy on the creation of grazing reserves in cattle-producing areas (Awogbade, 1987, as cited in Ogboru and Adejonwo-Osho, 2018). Herders from the north were responsible for cow rearing at the time. This explains why the grazing reserves Law was enacted by the Northern Regional Government in 1965. The Northern Region established grazing reserves in the Northern States as a result of that law. The Northern States integrated the law into their state laws when the Northern Region ceased to exist (Ogboru and Adejonwo-Osho, 2018). It is a legislation that governs the establishment, preservation, and management of grazing reserves, as well as other related matters. Section 3 of the Law defines lands that may be designated as a government grazing reserve as lands at the disposal of the government or native lands, as well as any properties on which the minister believes grazing should be protected or reserved (Ogboru and Adejonwo-Osho, 2018). These reserves were expected to boost productivity by providing crucial resources for livestock rearing and market access, as well as reducing existing conflicts between pastoralists and crop farmers who compete for resources (Ducrotoy *et al.*, 2017).

Based on the Grazing Reserve Law established by the Northern Region Government,grazing reserves covering an area of 4,288,725.6 hectares were established for herders to keep and graze their cattle (Okaiyeto and Muhammad, 1997). Many herders, however, use cattle movement to secure optimal grazing sites as a result of diminishing grazing lands (Fricke, 1979, as cited in Dahiru *et al.*, 2019). A study undertaken by Tanko *et al.* (2005) on the distribution of grazing reserves in northern Nigeria discovered that all of the reserves had been mis-used, with crop farmers and powerful government personnel encroaching on many of them. Few of these reserves were developed in accordance with the intended plan, and those that were in poor condition (Dahiru *et al.*, 2019).

2.2.2 GIS for site suitability analysis for grazing reserves

Environmental management has long been a test bed for the application of GIS as an analytical tool (Goodchild, 2003). A GIS provides an environment in which collected information and data can be used in a spatial framework to predict animal behaviour over time. Models designed to mimic real-world applications in a controlled environment enable manageable analysis of data associated with spatial locations, resulting in a better understanding of the landscape than field observations alone (Duvall, 2010, as cited in Umuhoza *et al.*, 2010).

Using GIS to analyse grazing capability at a landscape scale is not a new concept. A GIS was used to aid in the development of suitable areas for sheep grazing across Ethiopia's Awash River Basin in order to determine how efficient land managers were utilizing the land (Bizuwerk *et al.*, 2005). The study made use of Digital Elevation Models (DEM) to determine slope values for the study area, as well as water data layers to show areas that were close to water. Weighted values were assigned to areas based on erosion levels, average rainfall, distance from water, and slope gradient, and the results were analysed to determine overall suitability (Bizuwerk *et al.*, 2005).

Another study conducted in the semi-arid landscapes of Iran used GIS to depict graze land/ rangeland suitable for sheep grazing (Amiri, 2009). Using rangeland to graze sheep is a monetary and culturally intertwined process for Iranians. In the study, it identified areas suitable for such use in order to design grazing management plans that are sustainable to the land itself. Parameter such as Slope gradients, highly erosive areas, and areas near water were also used to generate an output of suitable grazing areas classified into three categories: moderately suitable, marginally suitable, and unsuitable.The use of GIS to perform the analysis was said to have provided greater accuracy and flexibility in determining the overall rangeland suitability (Amiri, 2009).

2.2.3 Factors that influence site suitability for grazing reserve

A variety of factors influence and affect the selection of a suitable site for any land use. Each criterion is depicted by a distinct map depicting a suitability area depending on its appropriateness for grazing reserve in this land suitability study. The relative weight of contribution to the grazing reserve is then graded on these suitability maps (Samuel *et al.*, 2020).

The following are the factors that influence site suitability for grazing reserves

(a) Soil depth

Soil depth is a critical factor in determining the amount of water and nutrients that can be stored in the soil profile, as well as the ability to support plant growth during periods of no rainfall or when irrigation is discontinued. Soil depth is also important in determining the profile's ability to support plant rooting and the crop's ability to withstand wind damage. Soil depth influences drainage, aeration, and water retention properties under irrigated conditions. Deep soils promote drainage and are thus ideal for irrigation of dry land crops. Crops cannot be expected to yield satisfactorily above critical soil depth ranges. Engelstad *et al.* (1961) discovered a positive relationship between soil depth and yield, which Lindstrom, Schumacher *et al.* (1986) confirmed.Rajakaruna and Boyd (2008) have stated that the depth of soil plays a significant role in determining the types of plants that can thrive in it. A greater depth of soil usually offers more water and nutrients to plants in comparison to shallow soil. Additionally, it is worth noting that most plants depend on soil for physical support, especially the tall woody plants such as shrubs and trees.

(b)Soil organic matter

Organic matter in soil increases the amount of water a soil can hold as well as the proportion of water available for plant growth in a pastoral grazing reserve. Furthermore, it is a major source of the plant nutrients phosphorus and sulfur, as well as the primary source of nitrogen for the majority of plants. Because it provides the majority of food for the community of heterotrophic soil organisms, soil organic matter has a significant impact on soil biology (Brady and Weil, 1999, as cited in Arora *et al.*, 2022).Overall soil organic matter has the potential to affect a range of functional soil properties (Murphy, 2015).Overall, the potential impact of soil organic matter on a variety of functional soil properties has been noted by Murphy (2015). Consequently, a higher quantity of organic carbon in the soil results in a greater suitability of the soil for the establishment of grazing reserves.

(c)Soil reaction (pH)

Soil pH indicates the solubility of the soil and thus, highlights potential availability or phyto-toxity of elements for crops. This also specifies the soil suitability for specific crops (Halder, 2013). Soil reaction (pH) is known to influence a wide range of chemical and biological processes in soils. Soil pH has a significant impact on mineral or nutrient solubility (Neina, 2019). Soil pH is the "master variable" of soil because it influences many physical, chemical, and biological properties and processes (Brady and, 1999; Sellan *et al.*, 2022). When the pH of the soil falls below a stipulated level, the solubility of aluminum and manganese ions increases, resulting in toxicity and lower yields. This affects grazing yield potential. Plant growth is influenced by soil acidity in a variety of ways. The most serious of these effects is thought to be toxicity, caused by increased mobility of soil aluminum (Black, 1992; Lopes *et al.*, 2021).

(d)Temperature

Temperature has been established to have three major effects on plant growth, which is a factor that influences the suitability of land for siting grazing land: growth stops below a critical temperature (typically 5 °C); the rate of growth varies with temperature; and extremely high temperatures have negative effects (FAO, 1976; Li *et al.*, 2022). The rate of growth rises more or less linearly with temperature between the minimum temperature for growth and the optimum temperature for photosynthesis, then reaches a plateau within the optimum temperature range before falling off at higher temperatures (Sys *et al.*, 1991; Jagadish *et al.*, 2021).

(e)Land use and land cover

The vegetation that is exploited for livestock and wildlife is the most important resource in rangeland development. There are significant differences in the genetic potential of plants to support livestock under extensive grazing, extending from major morphological realms to individual plant species. Certain vegetation types/covers are preferred by all animals over others. As a result, different vegetation types within a pasture receive varying degrees of use. Assuming that other distribution factors, such as water and terrain, remain constant, livestock will prefer the vegetation type that best meets their nutritional needs (Lemmessa, 2011). Cattle prefer open grasses to densely forested area.

(f)Rainfall

Rainfall is also a major factor influencing grazing land and rangeland suitability since it regulates water availability for rangeland plant development and greenness (Amiri *et al.*, 2014; Terfa and Suryabhagayan, 2015). Additionally, it controls soil moisture, which has an impact on plant development. Rainfall is important to agronomists and stockmen because it influences plant growing seasons and the availability of drinking water (Lemmessa, 2011).It is not advisable to establish grazing reserves in locations with relatively low rainfall (Balew *et al.*, 2022).

(g)Slope

Raynor *et al.* (2021) stated that "one of the most significant causes of poor livestock distribution on rangelands is rugged topography". The reluctance of livestock to use steep slopes is not entirely unwelcome, because these areas are frequently fragile, and valley bottoms can withstand grazing better. However, in many cases, slopes act as impediments to using benches and ridge tops above valley bottoms (Ebro, 2009; Atsbha, 2019).Steep slopes are not suitable for grazing reserves, as they offer less access to feed and water (Balew *et al.*, 2022). This makes it difficult for animals to get enough food and water, which can lead to them becoming ill or even dying. Additionally, slope influences soil erosion and runoff, which both have an impact on the growth of forage (Amiri *et al.*, 2014). On the other hand, flat terrain is suitable for the siting of grazing reserves (Amiri *et al.*, 2014; Terfa and Suryabhagayan, 2015).

(h)Altitude

Altitude has been established to have a marked influence on the kind, nature and productivity of grazing/ rangeland. Change in altitude corresponds to changes in both climatic and site conditions which in turn have significant influence on the plant communities (Kharkwal *et al.*, 2005). The decrease in temperature with increasing elevation drives vegetation patterns along altitudinal gradients (Crawford, 1989,as cited in Olsen *et al.*, 2022).The species richness of a specific plant community changes clearly along with the altitudinal range of its distribution (Malik *et al.*, 2014). The soil surface is more susceptible to rain, runoff, and erosion (by wind and water) at higher elevations. Such circumstances may hinder plant growth (Msadek *et al.*, 2022), rendering them unsuitable for grazing reserves.

(i)Proximity to roads, settlements and rivers

The distances to roads, settlements, and rivers are important because the distance to anthropogenic activities, or the distance to incentives for anthropogenic activities. These factor influences the suitability of the grassland for conservation.The proximity of rivers to anthropogenic activities can attract anthropogenic activities and, as a result, increase soil erosion (Vázquez-Quintero*et al.*, 2020).

The proximity to water source is an indispensable parameter for the siting of grazing reserves. All animals require drinking water at some time (Wang *et al.*, 2020). Locations close to water sources are more suitable for siting grazing reserves. In addition, such places are liable to grow better pasture than other parts. Source of water include river, streams, lakes and dams that attract herders from other places (Samuel *et al.*, 2020). Proximity to herders' settlement and areas with predominantly cattle keepers who need the grazing areas more (Houessou *et al.*, 2020).

Road/access road is a very important criterion in determining the suitability of a site for grazing reserves. This is because of the need to transport animals and their products from the grazing reserves to other places within the settlement or area, especially those that are not pastorally inclined (Samuel *et al.*, 2020). The creation of routes for cattle within built-up areas can be very difficult; therefore, this criterion is selected as an environmental factor for locating the grazing reserves closer to existing roads.The proximity to water source is an indispensable parameter for the siting of grazing reserves. Locations close to the road network are more suitable for siting grazing reserves.

The factors and their suitability classes are chosen after careful review of relevant literature and data available, as shown in Table 2.1.

Table 2.1 Factors for grazing reserve suitability analysis

Factors	Category	Rank	Level of Suitability	Source
Distance to water (m)	0-500	9	Highly Suitable	Adapted from Holechek *et al.* (1998)
	500-1000	7	Suitable	
	1000-3000	5	Moderately Suitable	
	3000-5000	3	Less Suitable	
	>5000	1	Not Suitable	
Slope (%)	0-8	9	Highly Suitable	Guenther *et al.* (2000)
	8-16	7	Suitable	
	16-30	5	Moderately Suitable	
	30-50	3	Less Suitable	
	>50	1	Not Suitable	
Distance to Road (Km)	>10	9	Highly Suitable	Adapted from Vázquez-Quintero *et al.*(2020)
	5-10	7	Suitable	
	2-5	5	Moderately Suitable	
	0.5-2	3	Less Suitable	
	<0.5	1	Not Suitable	
Land use and Land Cover	Bareland	7	Highly Suitable	Lemmessa (2011)
	Forest	9	Moderately Suitable	
	Farmland	5	Not Suitable	
	Built up	1	Not Suitable	
	Water	1	Not Suitable	
Soil pH	6.5-7	9	Highly Suitable	Sys *et al.* (1991)
	6-6.5	7	Suitable	
	5.5-6	5	Moderately Suitable	
Rainfall (mm)	400-900	9	Highly Suitable	Adapted from Kau *et al.* (2023)
	900-1200	7	Suitable	
Distance to Settlement (Km)	>10	9	Highly Suitable	Vázquez-Quintero *et al.*, (2020)
	10-5	7	Suitable	
	3-5	5	Moderately Suitable	
	1-3	3	Less Suitable	

	<1	1	Not Suitable	
Temperature (^{o}C)	25-27	7	Suitable	Sys *et al.* (1991)
	27-30	5	Moderately Suitable	
Elevation (m)	<400	9	Highly Suitable	Ostovari *et al.* (2019)
	400-500	7	Suitable	
	500-600	5	Moderately Suitable	
	>600	3	Less Suitable	
Soil Depth (cm)	>50	9	Highly Suitable	Adapted from Mazahreh *et al.* Hamoor (2019)
Organic carbon	>2	9	Highly Suitable	Sys *et al.* (1991)
	2-1.2	7	Suitable	
	1.2-0.8	5	Moderately Suitable	
	<0.8	3	Less Suitable	

2.2.4 Analytic hierarchy process

The Analytical Hierarchy Process (AHP) was developed by Saaty (1980). It is now one of the most important techniques for analysing land suitability. The AHP falls under the multi-criteria decision analysis approach and it is a useful technique for assisting planners and decision-makers in the analysis of data before making a final decision on future land-use changes (Bagheri *et al.*, 2013). The AHP has been designed to integrate with GIS tools that would enable it to determine the significance of the criteria used and to calculate the weights based on a scale of importance and expert opinion (Mohammad *et al.*, 2013).

The AHP is used to determine the weights of decision influencing factors on urban growth using GIS analysis functions. Additionally, it is a structured approach that can be used for complex decision-making situations with competing criteria (Javadian *et al.*, 2011 cited in Kandakoglu*et al.*, 2019). The weights of the factors in AHP are frequently identified using driven knowledge and driven data.

The main difficulty in applying the AHP model is that it requires the right experts with the most extensive knowledge and experience in the fields of suitability analysis and application to judge the factors in terms of their importance and weights (Reisi *et al.*, 2017). It is generally difficult to determine the relative weights of the factors used in land suitability analysis (Aburasa*et al.*, 2017). Thus, it is critical to use a technique with a strong ability to identify weights in order to reduce the difficulties associated with weighting factors. AHP is one of the most important techniques for analyzing spatial issues (Javadian *et al.*, 2011; Aburasa*et al.*, 2017).

AHP is a popular decision-making method (Saaty and Vargas, 2001; Dos Santos *et al.*, 2019). It is designed to select the best option from a set of alternatives based on a variety of criteria. The AHP allows for both inconsistency in decision making and provides a means to improve consistency. In this case, the decision maker or user will perform a simple pairwise comparison, which allows them to compare two elements at the same time (Rashidi and Sharifian, 2022).

The Pairwise comparison values are determined using the scale proposed by Saaty (1977). The following values are available for comparison: 9, 8, 7, 6, 5, 4, 3, 2, 1, 1/2, 1/3, 1/4, 1/5, 1/6, 1/7, 1/8, 1/9, with 9 representing absolute importance and 1/9 representing absolute triviality (Triantaphyllou and Mann, 1995). The AHP has been extensively studied and used in nearly all MCDM applications since its development due to its simplicity, ease of use, and great flexibility (Omar *et al.*, 2019).

2.2.5GIS-based multicriteria decision analysis(GIS-based MCDA)

Most geospatial decision issues contain many, conflicting, and incommensurate evaluation factors. To harmonise the issues, a set of criteria is used to evaluate, rank, and pick the best location choice (s). GIS-based MCDA can be defined in this context as a procedure that aggregates geospatial evaluation criteria and their relative importance into a final solution index map that can provide appropriate and useful information and insight into the decision-making problem. The fundamental reason for combining GIS and MCDA as separate areas of study is that they each have unique skills that complement one another. As a result, benefits for the growth of theoretical and applied research on the integration of GIS and MCDA may be seen in the context of their synergetic capabilities (Malczewski and Rinner, 2015; Muller *et al.*, 2019).

One essential component of the GIS-MCDA framework is that the importance of assessment criteria varies depending on the decision maker's value of judgments and the nature of the criterion values. As a result, GIS-MCDA techniques rely heavily on the criterion weighting procedures to discover and quantify important weights. Overtime, GIS-MCDA research have concentrated on weighing schemes from the perspective of the decision-makers, regardless of the information available for each criterion.These techniques have beenrevealed to establish subjective relevance weights that are simply based on the decision maker's preferences (Boroushaki, 2017). Several investigations on the various weighting schemes reveal that no subjective weighting method can create or guarantee a more accurate or precise set of weights. Furthermore, in complicated geographical decision-making problems, the decision-maker(s) may be unable or unwilling to provide consistent and precise numerical judgements about the relative relevance or weights of criteria. To address this issue, computer modelling, artificial intelligence, and information theory researchers did develop an entropy-based object-weighting method that determines the weights of the criteria by measuring the information co decision criteria (Karami and Johansson, 2014, as cited in Boroushaki, 2017).

The AHP multicriteria decision analysis techniques have been used in a Geographic Information Systems (GIS) framework for crops suitability analysis such as Moringa oleifera Tree Weyieb Sub Basin, Ethiopia (Wondimu and Ayansa, 2022), agricultural suitability in hilly zones, India (Zolekar and Bhagat 2015), rainfed farming (Kazemi and Akinci. 2018), rapeseed production, northwest Iran (Ostovari*et al.* 2020).

Selecting suitable areas for grazing reserves using a GIS-based Multicriteria is a process that can be used to determine the appropriateness of an area (land resource) for a specific use such as: agriculture, forestry, business, urban development, livelihood projects, e.t.c., while the basic premise of this method is that each aspect of the landscape has intrinsic characteristics that are in some degree either suitable or unsuitable for the activities being planned (Quinta-Nova and Natalia, 2018).

Spatial model inputs for suitability include a variety of biophysical, cultural, environmental and socio-economic factors. The results are often displayed on a map that is used to highlight areas from high to low suitability. A GIS suitability model typically answers the question, "Where is the best location?" Whether it involves finding the best location for a new road or pipeline, market, a new housing development, a new school or any other social amenity of land use (Rajendra, 2018; Pateland Sinha, 2019).

2.3 Review of Related Researches

Amiri (2009) conducted a study to determine water resources suitability for goats grazing in Ghareh Aghach watershed region, Isfahan province, Iran. Four criteria of water quality, water quantity, water distance and livestock information were integrated using GIS techniques. According to the results, water distance and accessibility to water is a most declining factor for suitability. A quality and quantity factor is a no limiting factor in part of study area. The results show that from 7158.69 ha of studied rangelands, 6245.93 ha (87.25%) classified as S1 class (with no limitation), 810.58 ha (11.32%) classified as S2 class (with low limitation), and 102.3 ha (1.43%) classified as

N class (non-suitable). Based on slope classes, more than 75% of slope is not suitable and less than 15% is very suitable.

Dessalegn (2009) identified suitable land areas for livestock production in Yabello district using GIS and Remote Sensing techniques. The study made use of LANDSAT 1986 and 2003 Remote Sensing Satellite Image analysis to determine the extent and pattern of rangeland change, and Multi Criteria Evaluation in a GIS environment to come up with the final suitability map. The study used weighted overlay technique of MCE in a GIS platform to arrive at the final land suitability for livestock species. The current analysis showed that, 31.6%, 31.5%, 18.2% and 26.9% of the total study area is most suitable for the production of cattle, sheep, goats and camels, respectively. Furthermore, it should be noted that the larger portion of the study area (39.2% and 38.2%) fell under the suitability class called marginally suitable for cattle and sheep, respectively. This could be attributed to the encroachment of the rangelands by the woody plant species which needs due treatment (e.g., rangeland rehabilitation or bush clearing) so as to reverse the scenario. In addition, the study revealed that more than half of the study area is permanently inaccessible.

Akomolafe (2015) used geospatial techniques and multicriteria decision analysis tool to determine and map appropriate locations for siting grazing reserves within Kaduna and Niger States. The various datasets collected and processed for the suitability mapping were categorized as biophysical, environmental and socioeconomic criteria. Ten factors and two constraints were used as criteria and weighted by Analytical Hierarchical Process (AHP) for the Multicriteria evaluation (MCE) in a GIS environment, to come up with the final suitability map which was classified according to FAO specifications. Results showed that 8% of the total area (9374.58 km^2) is highly suitable, 62%

(72212.59 km^2) is moderately suitable, 1% (615.09 km^2) is marginally suitable whereas 29% (33325.92 km^2) of the total area under consideration is not suitable for siting grazing reserves. Findings indicate that unsuitability or low suitability is as a result of steep slopes, unavailability of water resources, unfavourable climatic condition, unavailability of forage and nearness to settlements. Southern parts of Kaduna and south eastern area of Niger state were found to be suitable locations for establishing grazing reserves.

Terfa and Suryabhagavan (2015) analysed and mapped suitable areas for livestock production in Dire district using remote sensing and GIS techniques. The study made use of Landsat TM 2011 remote sensing satellite image for land-use/land-cover analysis, and Multi Criteria Evaluation in a GIS environment to come up with the final suitability map. In this study, factors such as rainfall, land-use/land- cover, soil, slope, access to water, veterinary service and livestock market centre were considered as factors. The result of the suitability analysis revealed that 5.6 %, 4.9 %, 5.4 %, and 10.1 % of study area was highly suitable for cattle, sheep, goat and camel, respectively; 44.75 %, 44.15 %, 45.5 % and 58.6 % of the land was classified as moderately suitable for cattle, sheep, goat and camel, respectively. Furthermore, 45.7 %, 46.5 %, 51 % and 31% of the land was classified as marginally suitable for cattle, sheep, goat and camel, respectively, and 4 %, 4.5 %, 1.1 % and 0.4 % was not suitable for cattle, sheep, goat and camel, respectively.

Emenike *et al.* (2016) determined and map out suitable rangelands for livestock grazing using AgrocropSDSS Multicriteria Evaluator (MCE) integrated with Geographic Information System (GIS) and Remote sensing techniques in Irepodun area of Osun state. Four bio-physical land parameters and two socio-economic factors including soil, topography (slope), climate (temperature and rainfall), land use/land cover, and distance to road and water were considered. The biophysical and socio-economic factors were processed and reclassified in AgrocropSDSS. The reclassified factors were overlaid in LULC of the area using weighted overlay to get suitable areas for livestock grazing. The result obtained showed that 10% of the study area were covered by water while 10%, 15%, 25% and 40% were unsuitable, moderately suitable, suitable and highly suitable for grazing respectively. The overall health of the vegetation as measured by the normalized differential vegetative index (NDVI) image showed poor, medium and good vegetation. The road was 100 kilometres off the settlement and Land owners were reluctant in releasing their land to herdsmen at no cost.

Rouhi-Moghaddam *et al.* (2017)evaluated rangeland suitability of Bagheran Birjand watershed area in Southern Khorasan Province, Iran using AHP-Fuzzy method. The maps of factors affecting the suitability (slope, production, erosion, quality of water resources, water need estimation percent and distance from water sources) were prepared in Geographic Information System (GIS). Data were standardized using fuzzy method and for weighting the criteria, the Analytic Hierarchy Process method was used. The results of AHP-Fuzzy model based on the weighted linear combination showed that 55.43% of rangelands were in suitability class of moderate suitability, 9.55% of the lands were in suitability class of low suitability and 6.21% of the lands were in non-suitability class. So, the limiting factors in this model for sheep grazing in the study area are water resources, high slope and vegetation.

Samuel *et al.* (2020) used GIS and AHP to produce a suitability map for a grazing reserve in Girei LGA, Adamawa State. Criteria such as grassland, water bodies, the road network, and herders' and non-herders' settlements were used. Findings of the study revealed that places like Ngarilde, Daware, Gokra, Jarenga, Modire Jabilamba, Sangere Usman, Sangere Njida, Jera Bakari, Kofare, Hotolore, Wuro Basambo, Langere, Ardo Maguwa, and Hurriyandu, which covered over fifty percent of the area, are highly suitable for grazing reserves in the LGA, while places such as Bajabure, Badarisa, Vunoklang, Labundo, Koh, and Wuro Dole are not suitable for such reserves. The study concluded that increases in population and urbanisation have taken over the existing grazing reserve, thereby making some of the places not suitable for grazing reserves. The study recommended that planning authorities extend development control to all gazetted routes and grazing areas to avoid further encroachment and use the integration of cattle routes and grazing areas as a guide for development control.

Zumo *et al.* (2020) used statistical analysis to identify viable, suitable and reliable criteria that can be adopted for establishing grazing areas in Yobe state of Nigeria that can completely eliminate or at least prevent conflicts between the herdsmen and the farming communities. It reveals the ambiguity of what type of grazing land policy is needed versus what type of grazing land policy is possible and gives insights into suitability or non-suitability of siting it. Four hundred sample data was used for the study. From the survey, 38.8% of respondents prefer private ranching as against the present government grazing reserve for establishing grazing lands and it should be sited in each senatorial district of the state. The grazing area to be allocated should not be less than $900km^2$ in size. The study further reveals that there is a significant relationship between frequency of conflict verses frequency of herdsmen migration and education background.

According to GSARS (2017), using a land resource map without assessing its reliability is pointless. As a result, Chabala *et al.* (2013) assessed the reliability of the map by conducting a physical study using a Geographic Positioning System (GPS) device where crop was located, noting the accompanying landform types and elevation. Additionally, using an error matrix, the validated data was compared to the produced map which indicated an acceptable limit. Perveen *et al.* (2013) also assessed the reliability of the decision support system map developed in another study using an existing cropping zone map. The existing cropping patterns on the cropping zone map were compared to the generated map and the results revealed a high level of agreement. In addition, Munene *et al.* (2017) assessed the suitability map via an error matrix table using field ground truth data obtained with a GPS device. The result shows a 65 percent accuracy, which is considered adequate for use as a guide in selecting suitable sites for soybean production.

Crop information derived from remote sensing plays an important role in improving agricultural statistics production by providing independent data for map accuracy verification (GSARS, 2017). In the Tuban Regency, Habibie *et al.* (2021) assessed the reliability of the maize suitability map created using NDVI. Fieldwork was used to collect data, and ground reference information was gathered by using a global positioning system (GPS) receiver to determine the locations of maize fields. The yield estimation on the highly suitable areas in Tuban Regency was high (77.81%).

2.3.1 Gaps in literature

Few studies have been conducted to analyse land suitability for siting grazing reserves in the northern part of Nigeria (Akomolafe, 2015; Zumo *et al*., 2020) with positive results. Moreover, the literaturesare filled with studies that utilised different factors without consideration for edaphic influence(Amiri, 2009; Dessalegn, 2009; Rouhi-Moghaddam *et al.*, 2017; Samuel *et al.*, 2020) to conduct suitability analyses for siting grazing reserves or rangelands. Moreover, Akomolafe (2015) did not include soil requirements like soil pH, soil depth, and organic carbon. This study aims to address the limitations of prior research, which overlooked key soil requirements for grazing reserves, including soil pH, soil depth, and organic carbon by explicitly including soil-related factors in the land suitability analysis, this study seeks to provide a more comprehensive understanding of the soil's contribution to the health of vegetation. The quality of soil directly impacts the carrying capacity and sustainability of grazing reserves, highlighting the importance of considering soil-related factors in land suitability assessments.

CHAPTER THREE

METHODOLOGY

3.1 Framework of Methodology

Figure 3.1 highlights a simplified work flow diagram for this study. It entails reconnaissance, data collection, reclassification (standardisation), calculation of weight, weighted overlay, production of suitability map and reliability of suitability map.

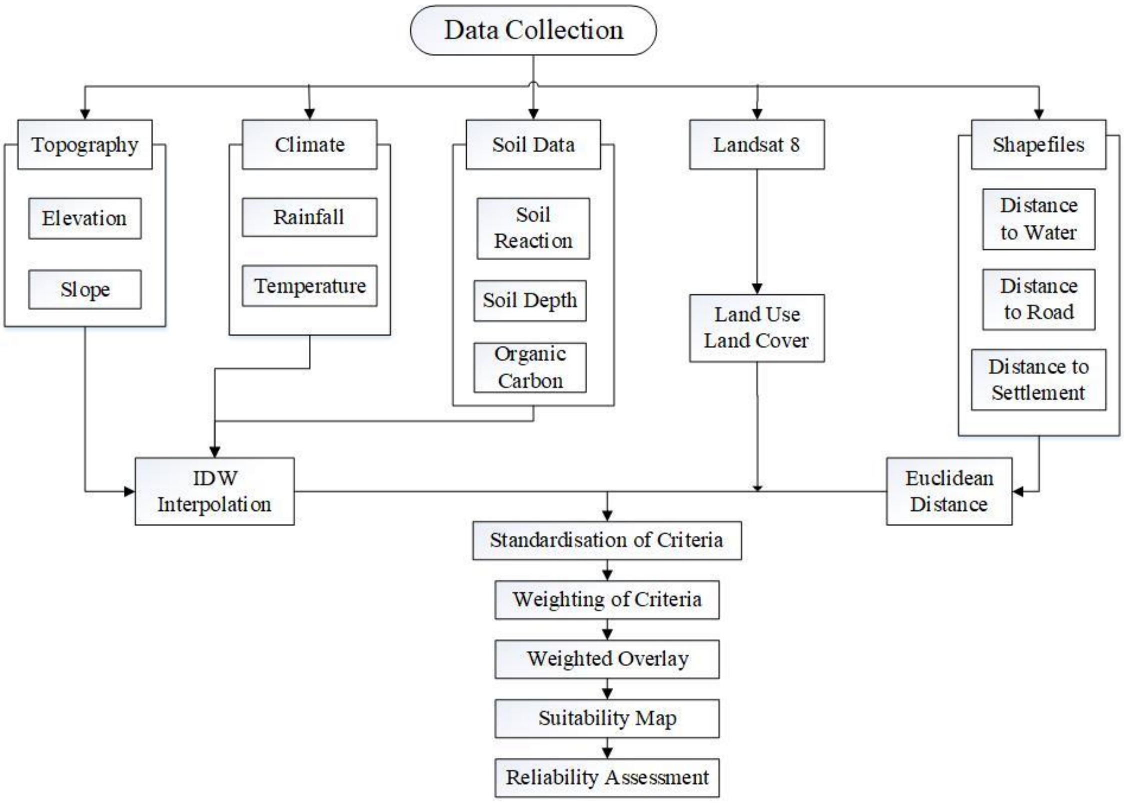

Figure 3.1 Workflow diagram

3.2 Data Types and Sources

This research is primarily based on information sourced from remotely sensed data, which entails data collected through remote sensing and other sources. The datasets utilised in this study were obtained from diverse sources, which are succinctly documented in Table 3.1. This comprehensive approach enabled the research to draw upon a broad range of relevant data, thereby enriching the findings and conclusions of the study.

Table 3.1 Data Types and Sources

S/N	Data	Resolution	Source	Purpose
1	Landsat 8 image of 2021	30 m	downloaded from the United State Geological Survey (USGS); (http://glovis.usgs.gov)	For LULC and NDVI map
2	Shuttle Radar Topographic Mission, (SRTM)	90 m	downloaded from the United State Geological Survey (USGS);	For creation of slope map

	(2000)		(http://glovis.usgs.gov)	
3	Soil data (soil pH, soil depth and soil organic carbon)	250 m	Downloaded from www.isric.org	For suitability map
4	Climate data (Temperature and Rainfall)		https://app.climateengine.org/climateEngine	For suitability map
5	Road, waterway and settlement shapefiles		grid3.gov.ng	For proximity maps

3.3 Software

The software used is presented in Table 3.2

Table 3.2 Software and Uses

S/N	Software	Uses
1	ArcGIS 10.8	For data preparation and GIS analysis
2	Microsoft Office 2016	For word processing and typesetting
3	Microsoft Excel 2016	For data analysis and presentation in the form of charts and graphs

3.3.1 Hardware

The hardware used are presented in Table 3.3

Table 3.3 Hardware and their uses

S/N	Hardware	Uses
1	Toshiba Tecra A50 notebook	For running all the software used for this research
2	HP printer	For printing

3.4 Data Preprocessing

The 2021 Landsat 8 image of the study area was classified into five (5) land use and land cover types namely: water, built up area, vegetation, farmland and bareland using supervised maximum likelihood classification algorithm in ArcGIS 10.8.The extraction of this data was done by using the clipping tool in the ArcGIS data management extension. To maintain consistency, all data were projected to the Mercator (world) UTM zone 31 and resampled to 30 m spatial resolution using the project raster and resample tools in the ArcGIS data management extension. This process has allowed for a more detailed and comprehensive analysis of the study area.

3.5 Generation of Criteria Maps

This stage is dedicated to tackling the GIS process and collaborating with spatial data input that portrays the parameters used to evaluate the accomplishment of site suitability map for grazing reserves.Following the establishment of criteria collection, each individual parameter is depicted as a map layer in GIS. The map layer that represents the criterion is commonly referred to as the criterion map. These maps are generated to provide a visual representation of each parameter to be used to produce the land suitability map for grazing reserves.

3.6 Criteria Standardization and Rating

The process of analysing land suitability involves utilising the criteria from various sources and scales. It is crucial to standardise all criteria on the same scale to ensure consistency and accuracy. Typically, the standardisation range value can be either 0 to 1 or 0 to 100 on a real number scale, depending on the choice of the operator or user. However, in the current study, a scale of 1 to 9 was employed. Each criterion's attribute was ranked based on its impact on land suitability for grazing reserve on a scale of 1 to

9. The reclassify spatial analyst tool in ArcGIS 10.8 was utilised to standardise each criterion according to expert opinion and literature standards, as shown in Table 2.1. This process helped to ensure that all the criteria was evaluated and ranked consistently. The use of a standardised scale also enabled the comparison of different criteria to determine their relative importance in land suitability analysis. Furthermore, the standardised scale facilitated the integration of various criteria to generate a comprehensive land suitability map. The map provides valuable information for decision-making in land use planning and management. Overall, the standardisation of criteria on a common scale is crucial for accurate and reliable land suitability analysis (Hoque*et al*., 2019).

3.7 Determination of Criteria Weights Using AHP

In order to determine criterion weights for decision-making, the Analytic Hierarchy Process (AHP) was utilised. This method involves assigning a value to each criterion based on their relative importance, a process that typically involves expert opinions, indigenous knowledge, field surveys, and comparing existing land use with location-specific characteristics. To create a comparison matrix, a larger value indicates greater importance for one criterion over another, while a value of 1 indicates equal importance (Saaty and Vargas 2001). Conversely, a value of 9 represents the absolute importance of one criterion over another, and a value of 1/9 represents the absolute triviality of one criterion over another. To normalise the comparison matrix, each number in the column was divided by the sum of the columns. Subsequently, the weight for each criterion was obtained by calculating the average of each row in the normalised matrix. This process is crucial for decision-making, as it allows decision-makers to prioritise criteria and make informed decisions based on their relative importance. Additionally, utilising expert opinions and indigenous knowledge helps to ensure that the decision-making process is sensitive to local contexts and factors. By comparing existing land use with location-specific characteristics, decision-makers can gain a better understanding of the potential impacts of their decisions on the environment and surrounding communities (Malek and Verburg, 2020).

Saaty (1980) has proposed a measure of consistency in pair-wise comparison, the consistency ratio (CR), which ranges from 0 to 0.1. A CR of 0 indicates perfect consistency, while a CR of > 0.1 implies inconsistency. According to Aina (2022) and Lamidi and Ijaware (2022), a CR of less than 0.1 is deemed acceptable, whereas values exceeding 0.1 indicate considerable inconsistency and unreliability in the pair-wise comparison.

3.8 Generation of Suitability Map

All the thematic layers, such as Land use and land cover, slope, temperature, precipitation, elevation, distance from water, distance from road, distance from settlement, soil organic carbon, soil pH, and soil depth, were grouped into five (5) distinct classes based on their impact on land suitability for grazing reserves. The data formats were converted to raster at a resolution of 30m to standardise criteria and reclassified into a common evaluation scale of 1–9. The highest score of 9 was designated as highly suitable, while the lowest score of 1 was deemed unsuitable for all factors considered for weighted overlay analysis. Using the Weighted overlay tool in ArcGIS 10.8, a suitability map was generated based on the weight obtained through AHP.

3.9 Reliability ofSuitability Map for Grazing Reserve

To validate the land suitability map, the normalised difference vegetation index (NDVI) was computed in ArcGIS 10.8 using the raster calculator. The following formula was used to calculate the NDVI map of the study area:

$$NDVI = \frac{(Band\ 5 - Band\ 4)}{(Band\ 5 + Band\ 4)} \tag{3.1}$$

Moreover, the zonal statistics tool in the spatial analyst extension of ArcGIS 10.8 wasused to calculate the mean NDVI value of each land suitability class. Areas with higherNDVI values were considered more suitable for the establishment of grazing reserves.

CHAPTER FOUR

RESULTS AND DISCUSSION

4.1 Land Use and Land Cover

Suitability criteria for establishing grazing reserves of the study area were generated as shown in Tables4.1. to 4.12 and Figures4.1. to 4.12.

4.2 Land Use Land Cover

The 2021 land use land cover class of the study area was generated in ArcGIS 10.8 and the result is presented in Table 4.1. The land use land cover map is shown in Figure 4.1.

Table 4.1 Land use land and cover statistics

LULC Class	Area (Sq. Km)	%
Vegetation	231.45	2.62
Barehand	8054.74	91.09
Farmland	497	5.62
Built up	51.61	0.58
Water-body	8.23	0.09
Total	**8843.04**	**100**

Table 4.1 reveals that the predominant land use and land cover category was bareland, comprising 91.09% of the entire area. This was the least followed by farmland (5.62%), while vegetation (2.62%), builtup (0.58%), and water-body (0.09%). The large area of bareland can be attributed to the fact that Zuru emirateis located within the Sudan savannah, a region characterised by grassy plains and scattered trees. Moreover, the notable extent of farmland indicates that agriculture holds a significant position as an economic pursuit within the emirate. Conversely, the limited area of builtup implies that the emirate remains comparatively underdeveloped.

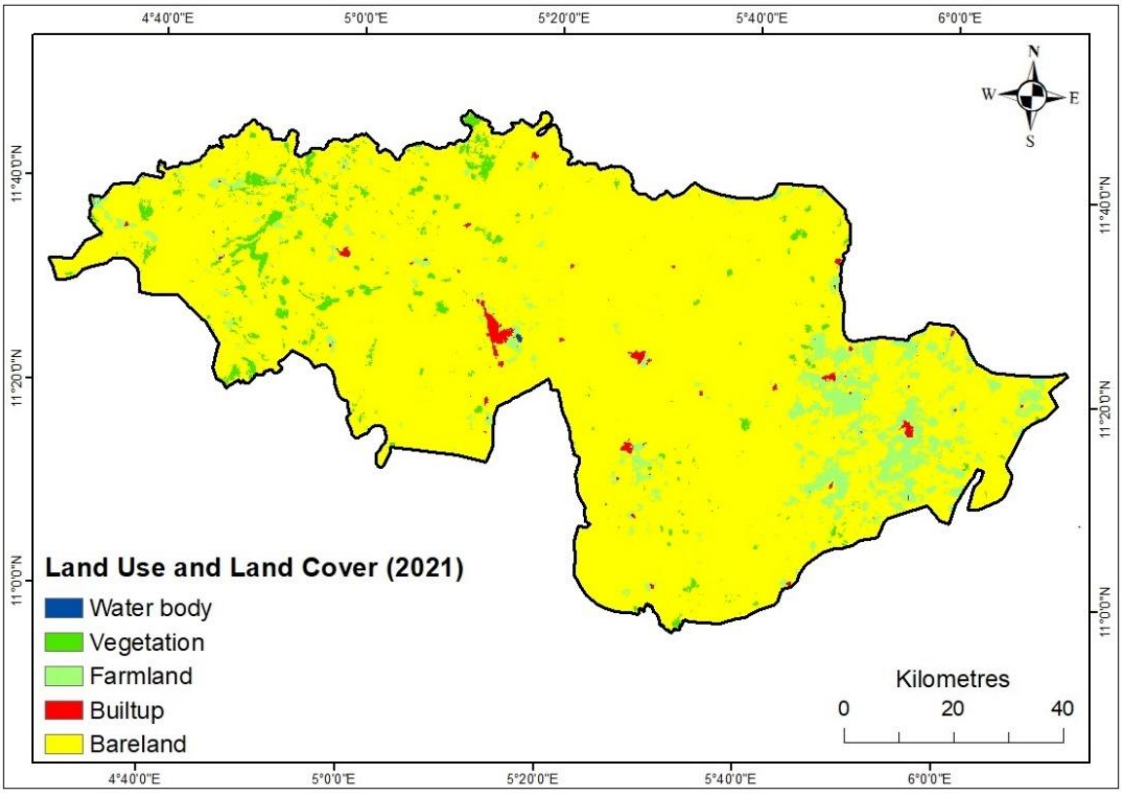

Figure 4.1 Land useand land cover of Zuru Emirate 2021

4.3 Suitability Analysis of Criteria

The land use and land cover classification map, along with the other criterion maps of the study area were created using ArcGIS 10.8 as shown in appendix I.The reclassified maps of all the criteria are shown in Figures 4.2 to 4.13.

4.3.1 Suitability analysis of land use land cover for siting grazing reserves

Table 4.2 presents the suitability analysis of the various land use and land cover types for siting of grazing reserve.

Table 4.2 SuitabilityAnalysis of land use and land cover for grazing reserves

Criterion	Name	Rank	%	Level of Suitability
	Vegetation	9	2.62	Highly Suitable
	Bareland	7	91.09	Suitable
LULC	Farmland	5	5.62	Moderately Suitable
	Built up	1	0.58	Not Suitable
	Water-body	1	0.09	Not Suitable
	Total		100	

Table 4.2 reveals that vegetation was classified as moderately suitable for siting grazing reserve, covering an area of 231.45sq.km, representing 2.62% of the total area. The largest area of the study area is occupied by bareland, covering 8054.74sq.km, accounting for 91.09% of the total land area, and it was deemed highly suitable for the establishment of grazing reserve. Farmland, on the other hand, covers an area of 497.00sq.km which represents 5.62% of the total land area, and it was categorized as moderately suitable for the grazing reserve. Smaller areas within the study area were occupied by built-up and water. Built-up, covering 51.61sq.km (0.58% of the total area), was considered not suitable for the establishment of grazing reserve, while water body covers 8.23 sq.km (0.09% of the total area) and was also classified as not suitable for siting grazing. Assuming water-body and terrain remain constant, livestock will prefer the vegetation type that will best meet their nutritional requirements (Lemmessa, 2011).

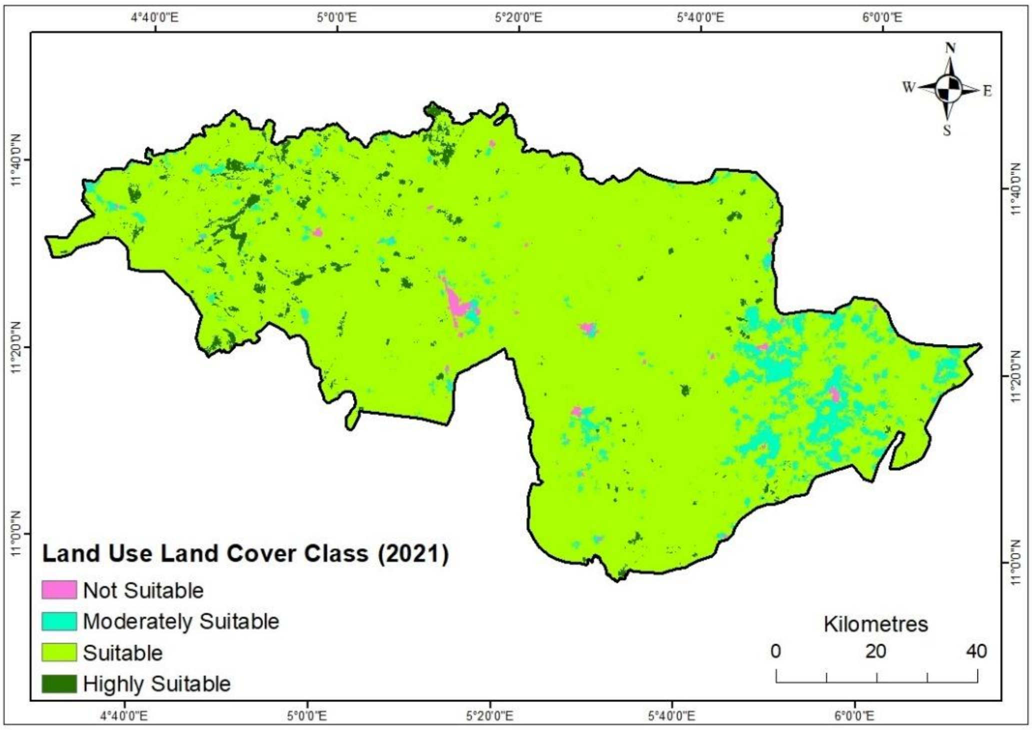

Figure 4.2 Suitability analysis of land use land cover for grazing reserve in 2021

4.3.2 Suitability of elevation for siting grazing reserves

Table 4.3 presents the results of a suitability analysis of elevation for siting grazing reserve. The Table 4.3 provides information on different elevation categories, their corresponding rankings, areas in sq.km, percentages and the level of suitability assigned to each category.

Table 4.3 Suitability analysis of elevation for grazing reserve

Elevation (m)	Rank	Area (Sq.km)	%	Level of Suitability
<400	9		61.34	Highly Suitable
400-500	7		36.27	Suitable
500-600	5		2.39	Moderately Suitable
>600	3		0.00	Less Suitable
Total			100	

As shown in Table 4.3, majority of the study area has elevation values below 400m, encompassing an area of 5424.45sq.km, which accounts for 61.34% of the total land area. As a result, these areas are considered highly suitable for siting grazing reserves. This indicates that significant part of the grazing reserves has elevations below 400m, making them highly suitable for the intended purpose. The locations with elevation values ranging from 400m to 500m are deemed suitable for the establishment of grazing reserves, covering an area of 3206.96sq.km, representing 36.27% of the total area. Places within the elevation range of 500m to 600m cover a smaller area of 211.31sq.km, accounting for 2.39% of the total area. These places are considered moderately suitable, suggesting that they may have some limitations, but are still reasonably suitable for siting grazing reserves. Areas with elevation values greater than

600m cover the smallest area, only 0.31sq.km, which is practically negligible compared to the total land area. Such areas are classified as less suitable, indicating that the land in this elevation range is less suitable for the establishment of grazing reserves. It is important to note that changes in altitude corresponds to alterations in both climatic and site conditions, which in turn have a significant influence on plant communities (Kharkwal *et al.*, 2005).

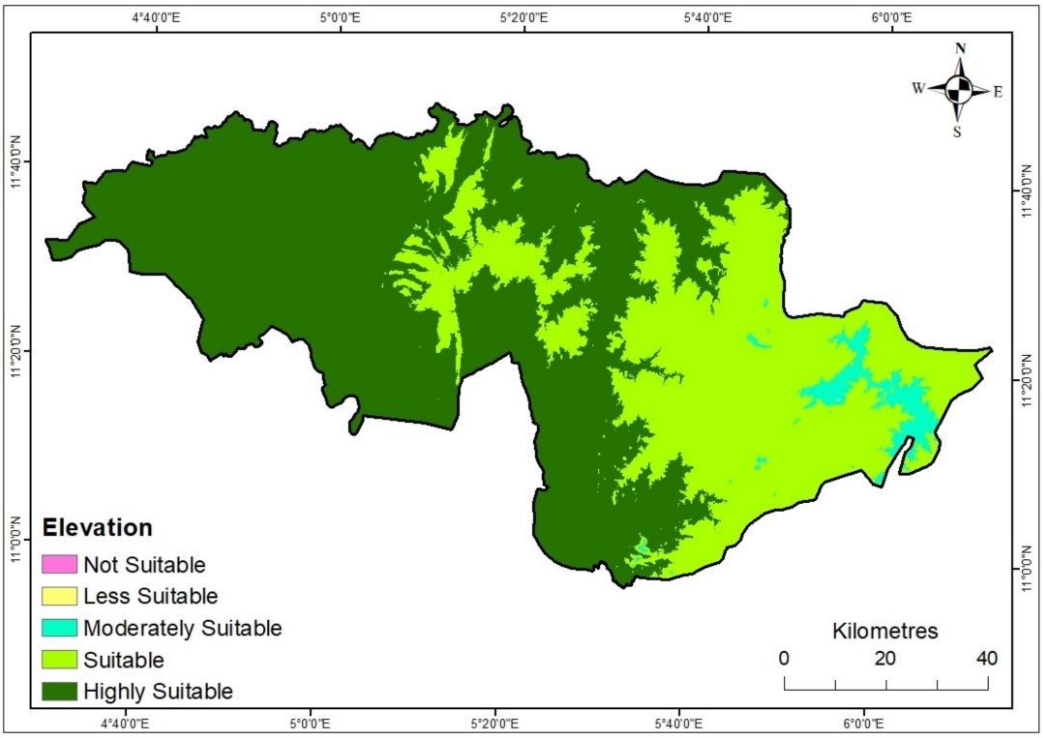

Figure 4.3 Suitability analysis of elevation for siting grazing reserve

4.3.3 Suitability analysis of slope for siting grazing reserve

Table 4.4 presents the results of suitability analysis of slope for the establishment of grazing reserves in Zuru Emirate, Kebbi state. The analysis assessed different slope categories based on their suitability for grazing purposes.

Table 4.4 Suitability analysis of slope for siting grazing reserve

Slope (%)	Rank	Area (Sq. Km)	%	Level ofSuitability
0-8	9	8560.68	96.81	Highly Suitable
8-16	7	215.97	2.44	Suitable
16-30	5	62.19	0.70	Moderately Suitability

30-50	3	4.20	0.05	Less Suitable
Total		8843.04	100	

Based on the results as presented in Table 4.4, vast majority of the study area falls within the 0-8% slope category, which is deemed highly suitable for establishing a grazing reserve. The highly suitable region encompasses a grand total of 8560.68sq.km, which accounts for approximately 96.81% of the total area. The 8-16% slope category, though still appropriate for siting grazing reserve, covers a significantly smaller land mass of 215.97sq.km, representing 2.44% of the total land area. In addition, the 16-30% slope category, with moderate suitability, covers 62.19sq.km, making up approximately 0.70% of the total land area. Lastly, the 30-50% slope category, which is the least suitable for grazing reserves, covers the smallest area of 4.20 squaresq.km, accounting for just 0.05% of the total area. According to Raynor *et al.* (2021), rugged topography is one of the primary causes of poor livestock distribution on rangelands. This is due to the fact that steep slopes offer limited access to feed and water, as highlighted by Balew *et al.*, (2022). As a result, animals may struggle to obtain adequate nourishment and hydration, potentially leading to illness or even death. Furthermore, the slope of the terrain can affect soil erosion and runoff, both of which can impact forage growth (Amiri *et al.*, 2014).

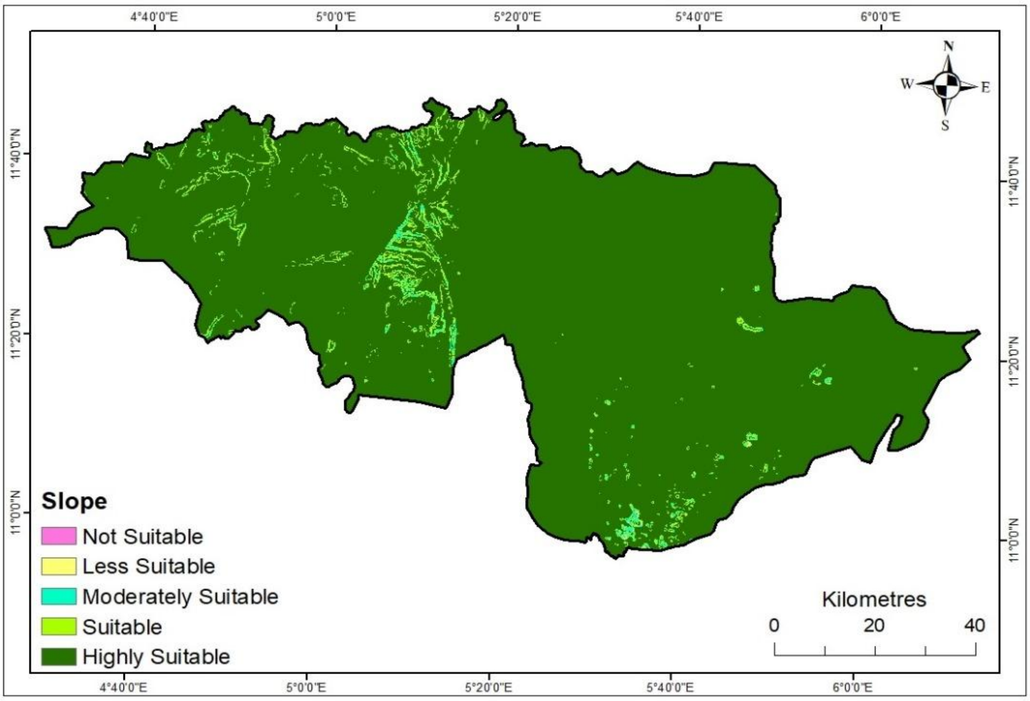

Figure 4.4 Suitability analysis of slope for siting grazing reserve

4.3.4 Suitability analysis of rainfall for siting grazing reserve

Table 4.5 shows the results of suitability analysis of rainfall for siting grazing reserve. It categorized two (2) different rainfall range and provides rankings, area coverageand the level of suitability for each category.

Table 4.5 Suitability analysis of rainfall for siting grazing reserve

Rainfall(mm)	Rank	Area (Sq. Km)	%	Level of Suitability
400-900	9	2161.81	24.45	Highly Suitable
900-1200	7	6681.23	75.55	Suitable
Total		8843.04	100	

Table 4.5illustrates that within the study area, there exists a considerable portion (24.45%) of land with highly suitable rainfall levels ranging from 400-900mm, covering an expansive area of 2161.81sq.km. Furthermore, a greater portion (75.55%) of the study area falls within the suitable rainfall range (900-1200mm), covering a substantial area of 6681.23sq.km. This valuable information can inform land

management decisions, particularly in regards to the establishment of grazing reserves. It is noteworthy that rainfall is a crucial factor that influences grazing land and rangeland suitability, given that it regulates water availability for rangeland plant development and greenness (Amiri *et al.*, 2014; Terfa and Suryabhagayan, 2015).

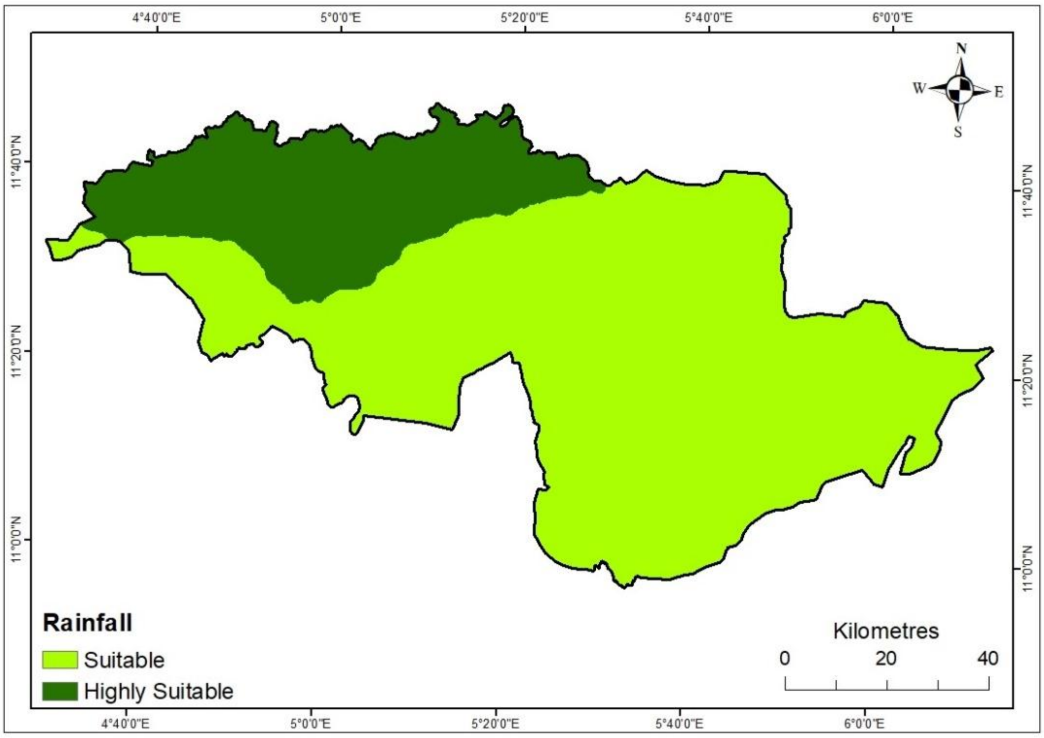

Figure 4.5 Suitability analysis of rainfall for siting grazing reserve

4.3.5 Suitability analysis of temperature for siting grazing reserve

Table 4.6 shows the results of suitability analysis of temperature for siting grazing reserve. Thedifferent temperature ranges and their corresponding levels of suitability were evaluated for the purpose of establishing grazing reserves.

Table 4.6 Suitability analysis of temperature for siting grazing reserve

Temperature (°C)	Rank	Area(Sq. Km)	%	Level of Suitability
25-27	7	7803.18	88.24	Suitable
27-30	5	1039.86	11.76	Moderately Suitable
Total		8843.04	100	

Table 4.6 demonstrates that the temperature range of 25-27 degrees Celsius (°C)is suitable for designating grazing reserves, which spans 7803.18sq.km, accounting for approximately 88.24% of the total area. The temperature range of 27-30°C, slightly higher, is moderately suitable, however, it only covers a smaller portion of the total area (11.6%), occupying 1039.86 sq.km. The impact of temperature on plant growth has been established as a critical factor affecting the suitability of land for grazing purposes, with three significant effects. These effects include the cessation of growth below a critical temperature, variations in growth rates with temperature, and negative effects at extremely high temperatures (FAO, 1976; Li *et al.*, 2022).

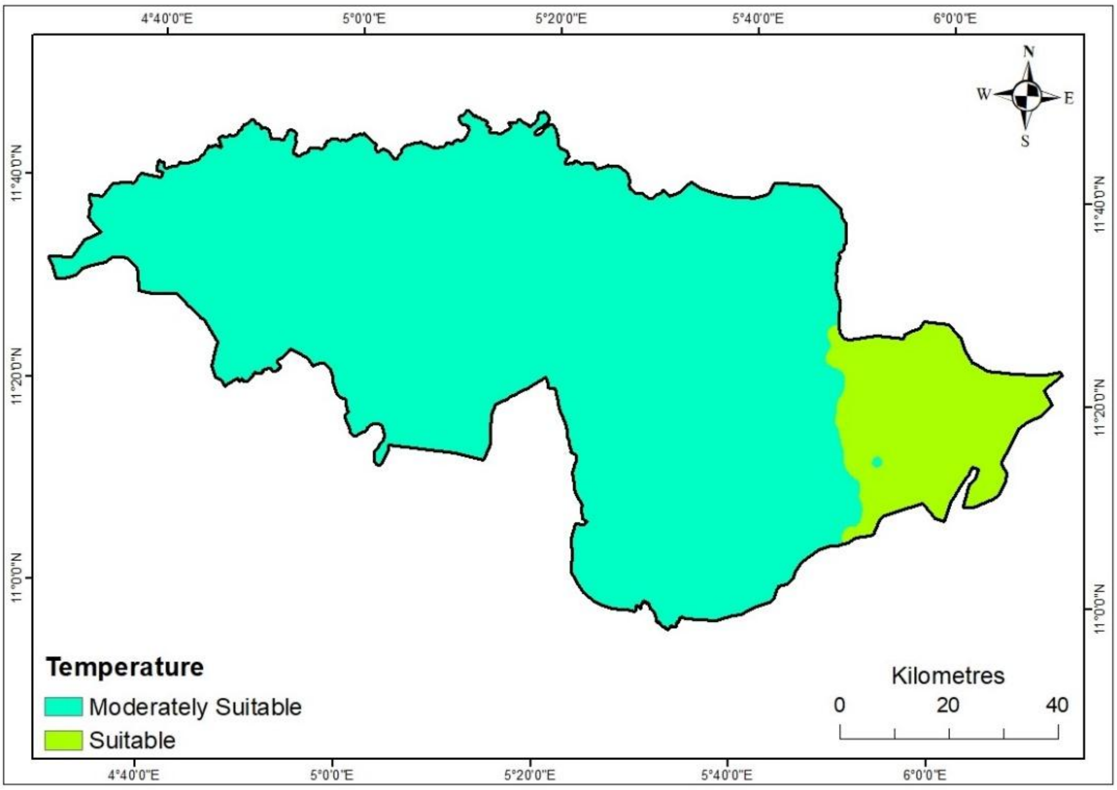

Figure 4.6 Suitability analysis of temperature for siting grazing reserve

4.3.6 Suitability analysis of soil depth for siting grazing reserves

The suitability analysis of soil depth for siting grazing reserve in the study area was conducted and the results are presented in Table 4.6.

Table 4.7 Suitability analysis of soil depth for siting grazing reserve

Soil depth(cm)	Rank	Area (Sq. Km)	%	Level of Suitability
<100	5	404.28	4.57	Moderately Suitable
100-150	7	8409.64	95.10	Suitable
>150	9	29.12	0.33	Highly Suitable
Total		8843.04	100	

Based on Table 4.7, the vast majority of land in Zuru Emirate is categorized as suitable, with 95.10% of the total area having a soil depth ranging from 100cm to 150cm. A smaller proportion of land falls under the moderately suitable category, with a soil depth of less than 100cm, accounting for 4.57% of the total area. The highly suitable category, characterized by soil depth greater than 150cm, only represents 0.33% of the entire area. This valuable information can aid policymakers and land managers in making informed decisions regarding the establishment of grazing reserves in the study area, taking into account the varying levels of suitability based on soil depth. Rajakaruna and Boyd (2008) assert that the depth of soil is a crucial factor in determining the variety of plants that can flourish in it. In contrast to shallow soil, a greater depth of soil generally provides more water and nutrients to plants.

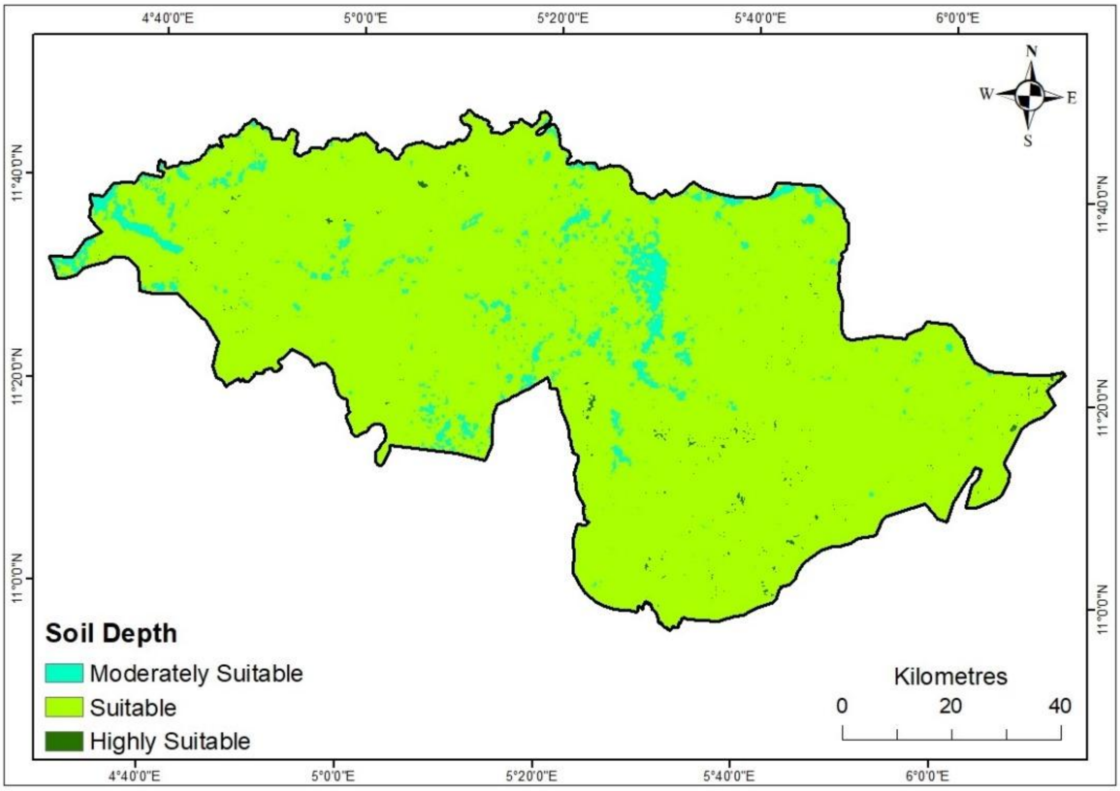

Figure 4.7 Suitability analysis of soil depth for sitinggrazing reserve

4.3.7 Suitability analysis of soil organic carbon for siting grazing reserves

Table 4.8 presents the distribution of soil organic carbon in the study area based on its suitability for the establishment of a grazing reserve as presented in Figure 4.7 above.

Table 4.8 Suitability analysis of soil organic carbon for siting grazing reserve

Soil Category (%)	Rank	Area (Sq. Km)	%	Level of Suitability
>2	9	2297.99	25.99	Highly Suitable
1.2-2	7	5779.19	65.35	Suitable
0.8-1.2	5	725.04	8.20	Moderately Suitable
<0.8	3	40.82	0.46	Less Suitable
Total		8843.04	100	

According to Table 4.8, the highly suitable category encompasses an extensive area of 2297.99 sq.km, representing 25.99% of the total area. This classification is attributed to areas with soil organic carbon (SOC) levels that exceeds 2%, thereby rendering them suitable for grazing reserve. The suitable category, which is the largest classification, covers an area of 5779.19 sq.km, representing 65.35% of the total area. The moderately suitable class, which is the second smallest category, covers an area of 725.04sq.km, representing 8.20% of the total area. Lastly, less suitable classification is the smallest, covering an area of 40.82sq.km, representing 0.46% of the total area. Areas with soil organic carbon levels below 0.8% are considered less suitable for siting grazing reserves. Murphy (2015) has highlighted the potential influence of soil organic matter on various functional soil properties. Accordingly, a higher concentration of organic carbon in the soil leads to a greater suitability of the soil for grazing reserve establishment.

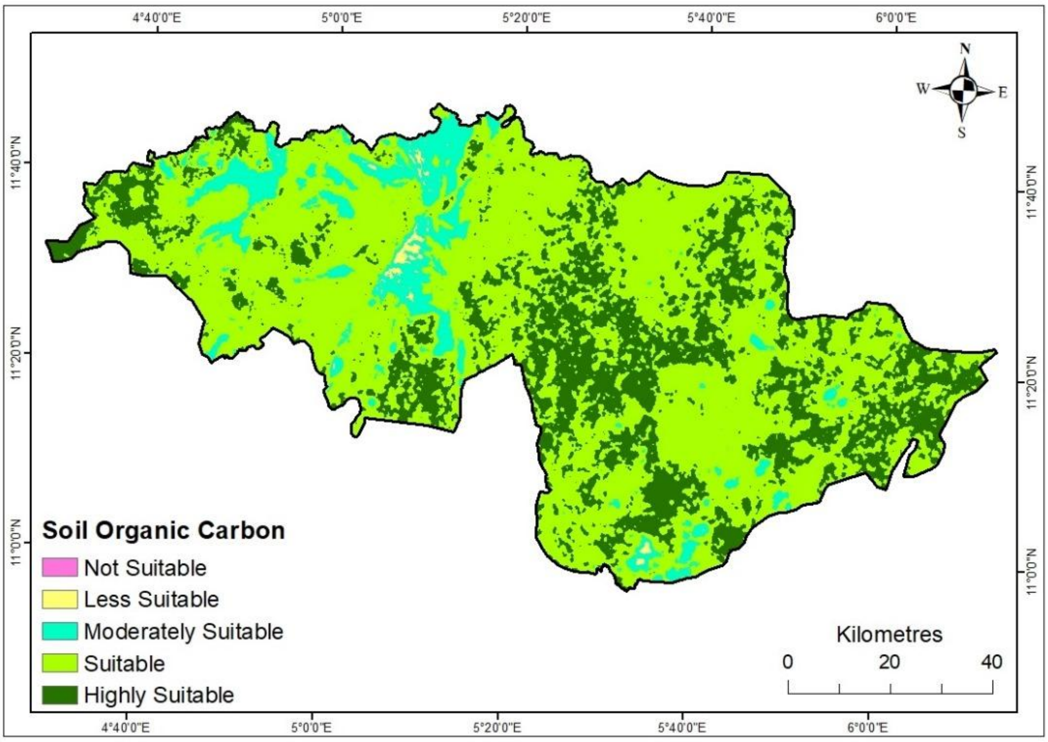

Figure 4.8 Suitability analysis of soil organic carbon for siting grazing reserve

4.3.8 Suitability analysis of soil pH for siting grazing reserves

Table 4.9 presents the results of suitability analysis of soil reaction (pH) for siting grazing reserves. Soil pH is an important factor to consider when determining the suitability of an area for siting grazing reserve, as it affects the availability of nutrients and the overall health of the vegetation. The suitability map of soil pH is illustrated in Figure 4.8.

Table 4.9 Suitability analysis of soil pH for siting grazing reserve

Soil Category	Rank	Area (Sq. Km)	%	Level of Suitability
6.5-7	9	36.66	0.41	Highly Suitable
6-6.5	7	7498.07	84.79	Suitable
5.5-6	5	1308.31	14.79	Moderately Suitable
Total		8843.04	100	

According to Table 4.9, grazing reserves are highly suitable in areas with a pH range of 6.5-7. This pH range covers a total area of 36.66sq.km, which represents only 0.41% of the analysed region. Grazing reserves can also be located in areas with a pH range of 6-6.5, which represents a much larger area of 7,498.07sq.km, accounting for 84.79% of the total area. Similarly, moderately suitable areas for grazing reserve establishment have a pH range of 5.5-6, which covers an area of 1,308.31sq.km, or 14.79% of the analysed region. Overall, Table 4.8 shows that a majority of the analysed area falls within the suitable category, with the largest proportion being the pH range of 6-6.5 and the smallest area being the highly suitable pH range of 6.5-7. When the pH level of the soil decreases below a predetermined level, it leads to the increased solubility of aluminium and manganese ions, which can cause toxicity and reduced yields, particularly impacting the potential grazing yield. Soil acidity can also have a range of effects on plant growth, with the most severe being toxicity, caused by the enhanced mobility of soil aluminium (Black, 1992; Lopes *et al.*, 2021).

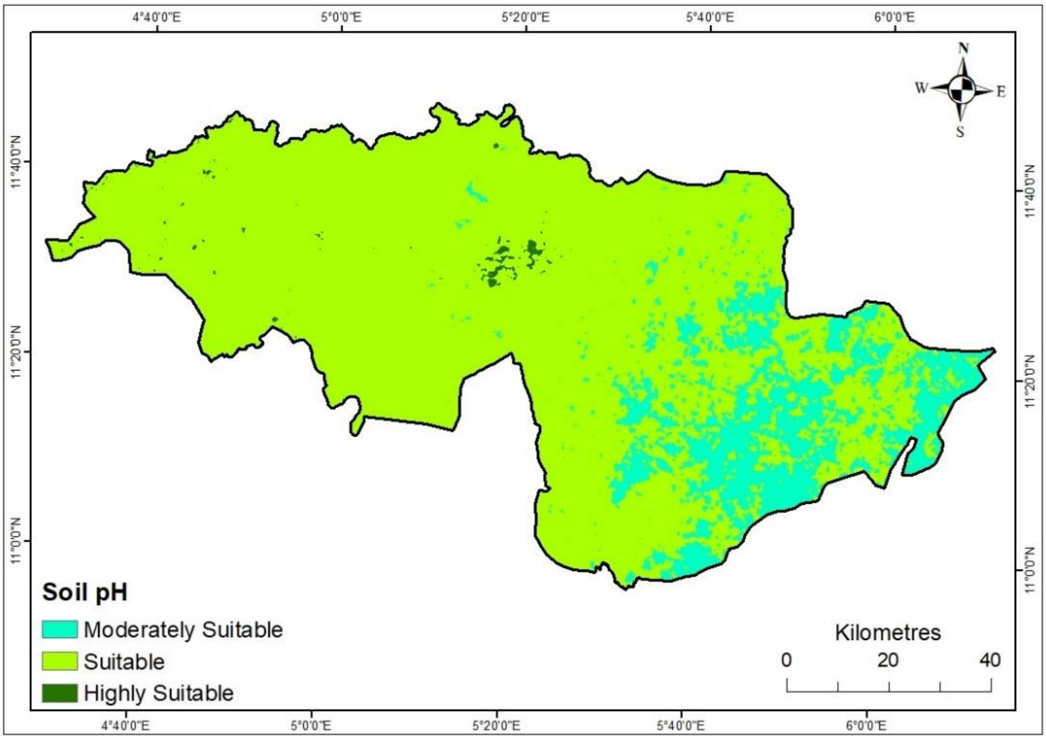

Figure 4.9 Suitability analysis of soil pH for siting grazing reserve

4.3.9 Suitability analysis of distance from road for siting grazing reserve

Suitability analysis of distance from the road for siting a grazing reserve was conducted and the results are presented in Table 4.10 and Figure 4.10.

Table 4.10 Suitability analysis of distance from road for siting grazing reserves

Category (m)	Rank	Area (Sq. Km)	%	Level of Suitability
<250, >10000	1	1069.41	12.09	Not Suitable
250-1000	9	573.72	6.49	Highly Suitable
1000-2000	7	1842.63	20.84	Suitable
2000-5000	5	2912.52	32.94	Moderately Suitable
5000-10000	3	2444.76	27.65	Less Suitable

Total	8843.04	100

According to Table 4.10, areas that fall within the range of less than 250m or more than 10,000m fromroadsoccupy an area of 1069.41sq.km, which is approximately 12.09% of the total area and were not suitable for the establishment of grazing reserve. The areas that lie between 250m to 1000m from roads cover an area of 573.72sq.km, which is about 6.49% of the total area and are deemed highly suitable for the siting of grazing reserve. Locations between 1000m and 2000m from roadscover a wider area of 1842.63sq.km, which comprises approximately 20.84% of the total area and are categorized as suitable for the location of grazing reserves. Places that are situated between 2000m and 5000m from roads occupy a significant area of 2912.52sq.km, which corresponds to about 32.94% of the total area and were considered moderately suitable. Lastly, areas that are between 5000m and 10000m away from roads covers an area of 2444.76sq.km, which accounts for approximately 27.65% of the total area and were described as less suitable. Locations close to the road network are more suitable for siting grazing reserves.Areas close to the road network are more suitable for grazing reserve siting,this is because of the need to transport animals and their products from the grazing reserves to other places within the settlement area or to other destinations, especially those that are not pastorally inclined (Samuel *et al.*, 2020).

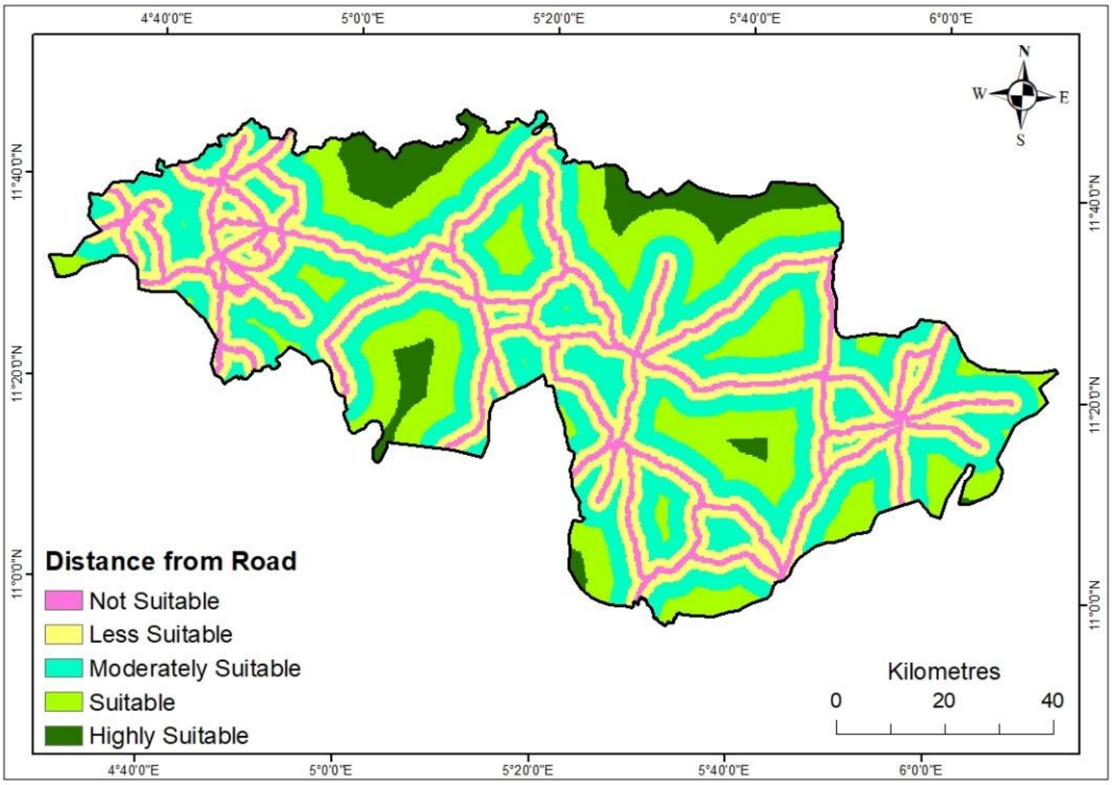

Figure 4.10 Suitability analysis of distance from road for siting grazing reserve

4.3.10 Suitability analysis of distance from river for siting grazing reserve

Table 4.11 shows the results of the suitability analysis conducted on the distances from rivers to determine the suitable location for grazing reserves. The study classified and ranked five different distance ranges based on their suitability for establishing grazing reserve. The suitability map of distance from river is illustrated in Figure 4.10.

Table 4.11 Suitability analysis of distance from river for siting grazing reserve

River distance (m)	Rank	Area (Sq. Km)	%	Level of Suitability
0-500	9	279.46	3.16	Highly Suitable
500-1000	7	278.13	3.15	Suitable
1000-3000	5	840.27	9.50	Moderately Suitable
3000-5000	3	1082.44	12.24	Less Suitable
>5000	1	6362.73	71.95	Not Suitable
Total		8843.04	100	

The analysis of suitability as shown in Table 4.11 indicates areas that are within 0-500m and 500-1000m from the river are highly suitable and suitable respectively, for the location of grazing reserves. As the distance from the river increases (1000-3000m and 3000-5000m), the level of suitability decreases too moderately suitable and less suitable. Ultimately, areas that are situated more than 5000m away from rivers are deemed unsuitable for siting of grazing reserves.The proximity to a water source is an essential factor for the siting of grazing reserves, as all animals require drinking water at some point (Wang *et al.*, 2020). Therefore, areas in close proximity to water sources are more appropriate for siting grazing reserve.

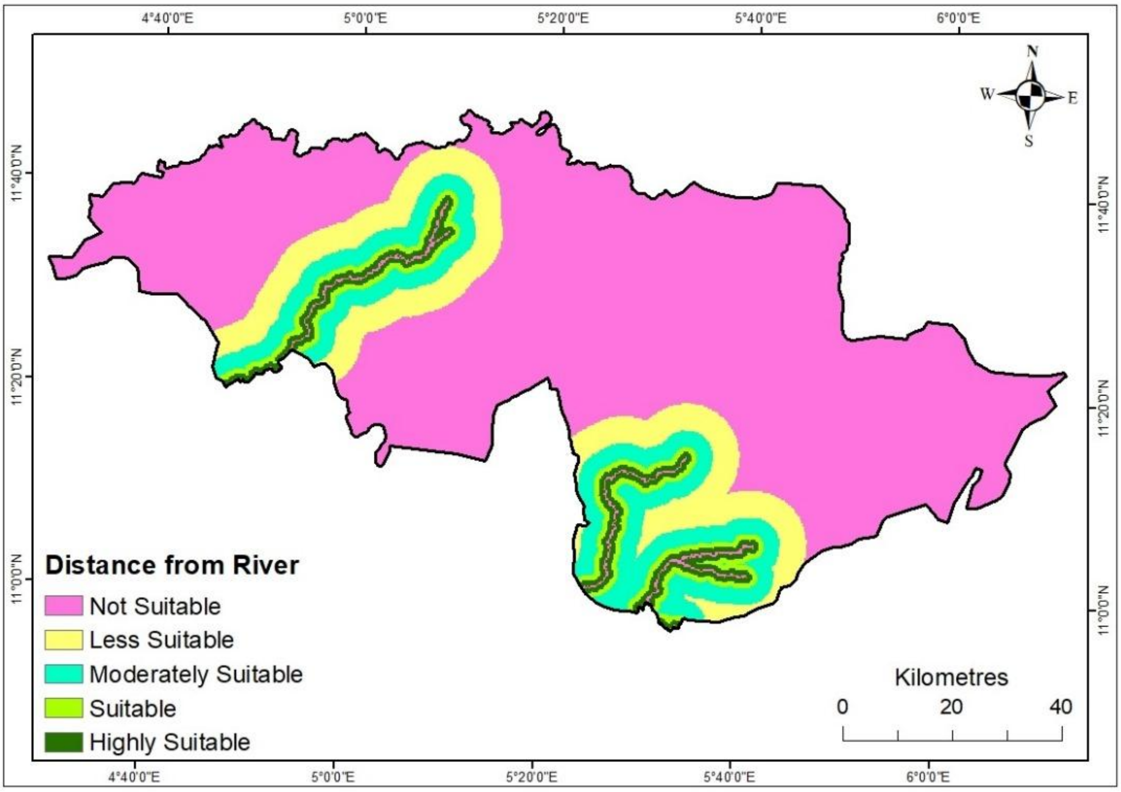

Figure 4.11 Suitability analysis of distance from river for siting grazing reserve

4.3.11 Suitability analysis of distance from settlement for siting grazing reserves

The suitability analysis of the distance from settlement for the siting of grazing reserve was evaluated and the results is presented in Table 4.12. The analysis categorizes different distance ranges and provides rankings, area coverage, and levels of suitability for each category. This suitability analysis helps in understanding the distribution and suitability of land for the location of grazing reserve based on its distance from settlements.

Table 4.12 Suitability analysis of distance from settlement for siting grazing reserve

Settlement (m)	Rank	Area (Sq. Km)	%	Level of Suitability
>10000	9	1455.75	16.46	Highly Suitable
5000-10000	7	3755.68	42.47	Suitable
3000-5000	5	1997.39	22.59	Moderately Suitable
1000-3000	3	1414.98	16.00	Less Suitable
<1000	1	219.23	2.48	Not Suitable
Total		8843.04	100	

Table 4.13 has revealed that areas located more than 10000m away from settlements are highly suitable for the establishment of grazing reserves. These regions cover a vast area of 1455.75sq.km, which accounts for 16.46% of the total area. The areas which are situated between 5000m to 10000m from settlements were identified as suitable for the location of grazing reserves. These places cover the largest expanse of 3755.68sq.km, accounting for 42.47% of the total area. The areas that are moderately suitable for the establishment of grazing reserves are those located between 3000m to 5000m from settlements. They span over an area of 1997.39sq.km, which accounts for 22.59% of the total area. The less suitable areas that are situated between 1000m to 3000m from settlements cover an area of 1414.98sq.km, accounting for 16.00% of the total area. Areas that are situated less than 1000m away from settlements were deemed not suitable for the location of grazing reserves. These areas are the smallest in expanse, covering 219.23sq.km, which accounts for 2.48% of the total area. It is recommended

that grazing reserves be established in close proximity to the settlement of herders and areas dominated by cattle keepers who require grazing areas the most (Houessou *et al.*, 2020).

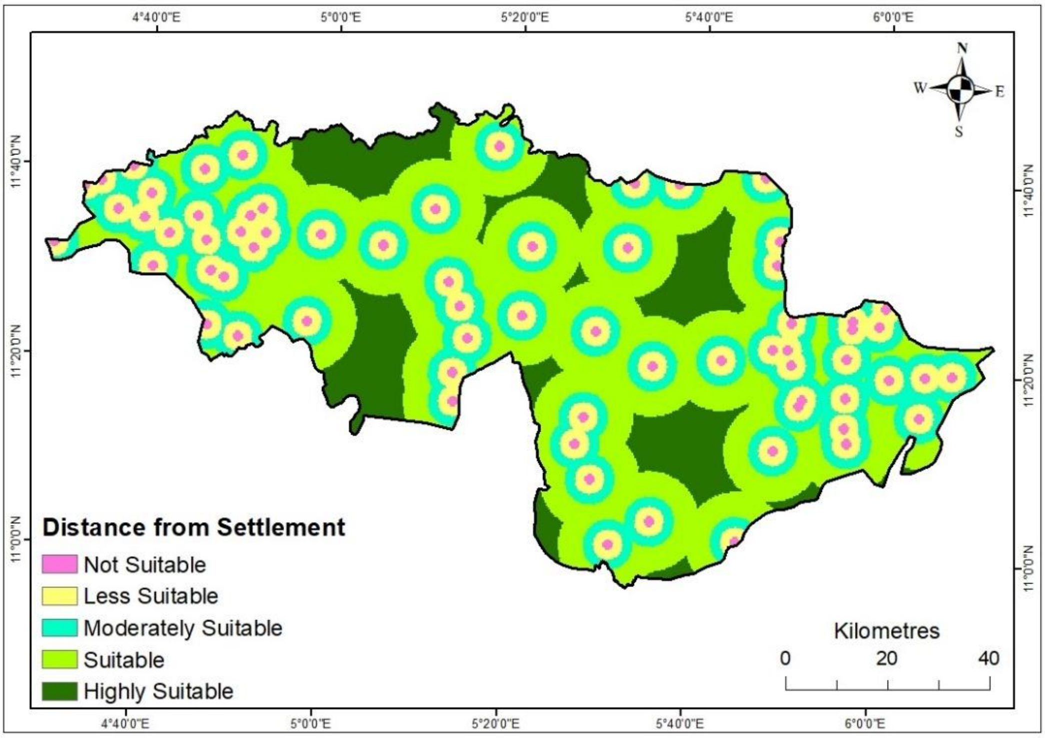

Figure 4.12 Suitability analysis of distance from settlement for siting grazing reserve

4.4 Evaluation of Criteria Weights

4.4.1 AHP pair-wise comparison matrix

Table 4.13 presents a pairwise comparison matrix of the Analytic Hierarchy Process (AHP) utilized for the evaluation of distinct criteria in the establishment of grazing reserves in Zuru Emirate, Kebbi State. The criteria employed in the pair-wise comparison are Distance from water (DW), Slope (SL), Distance from Road (DR), Land use and Land Cover (LC), Soil reaction pH, Rainfall (RF), Distance from Settlement (DS), Temperature (TP), Elevation (EL), Soil Depth (SD), and Soil Organic carbon (SOC).

Table 4.13 AHP pair-wise comparison matrix

Criteria	DW	SL	DR	LC	pH	RF	DS	TP	EL	SD	OC
DW	1	5/2	3	2/5	4	1/3	2	7/3	7/2	4	4
SL	2/5	1	3/5	1/4	5/2	1/3	1/3	5/4	5/2	2	3
DR	1/4	5/3	1	5/9	7/2	4/5	1/4	8/3	4	3	3
LC	5/2	4	2	1	7	3	5/2	4	5	6	6
pH	1/4	2/5	2/7	1/7	1	3/7	1/3	3/2	2	2/3	2/3
RF	3	3	5/4	1/3	7/3	1	3/5	1	8/5	9/5	7/2
DS	1/2	3	1/2	2/5	3	5/3	1	2	2	3	3
TP	3/7	4/5	3/8	1/4	2/3	1	3/5	1	3/2	5/3	5/3
EL	2/7	2/5	1/4	1/5	1/2	5/8	1/2	2/3	1	3/2	2
SD	1/4	1/2	1/3	1/6	3/2	5/9	1/3	3/5	2/3	1	3
OC	1/4	1/3	1/3	1/6	3/2	2/7	1/3	3/5	1/3	1/4	1
Total	9.1	17.6	9.9	3.9	27.5	10	8.8	17.6	24.1	24.9	30.8

4.4.2 Normalized AHP pair-wise comparison matrix

Table 4.14 presents a normalized pairwise comparison matrix of the AHP that is utilized for the evaluation of different criteria concerning the establishment of grazing reserve in the study area.

Table 4.14 Normalized AHP pair-wise comparison matrix

	DW	SL	DR	LC	pH	RF	DS	TP	EL	SD	OC	Weight
DW	0.11	0.14	0.30	0.10	0.15	0.03	0.23	0.13	0.15	0.16	0.13	0.15
SL	0.04	0.06	0.06	0.06	0.09	0.03	0.04	0.07	0.10	0.08	0.10	0.07
DR	0.03	0.09	0.10	0.14	0.13	0.08	0.03	0.15	0.17	0.12	0.10	0.10
LC	0.27	0.23	0.20	0.26	0.25	0.30	0.28	0.23	0.21	0.24	0.19	0.24
pH	0.03	0.02	0.03	0.04	0.04	0.04	0.04	0.09	0.08	0.03	0.02	0.04
RF	0.33	0.17	0.13	0.09	0.08	0.10	0.07	0.06	0.07	0.07	0.11	0.12
DS	0.05	0.17	0.05	0.10	0.11	0.17	0.11	0.11	0.08	0.12	0.10	0.11
TP	0.05	0.05	0.04	0.06	0.02	0.10	0.07	0.06	0.06	0.07	0.05	0.06
EL	0.03	0.02	0.03	0.05	0.02	0.06	0.06	0.04	0.04	0.06	0.06	0.04
SD	0.03	0.03	0.03	0.04	0.05	0.06	0.04	0.03	0.03	0.04	0.10	0.04
OC	0.03	0.02	0.03	0.04	0.05	0.03	0.04	0.03	0.01	0.01	0.03	0.03
Total	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00

Distance to water: DW; Slope: SL; Distance from Road: DR; Land use Land Cover: LC; Rainfall: RF; Soil Reaction: pH; Distance from Settlement: DS; Temperature: TP; Elevation: EL; Soil Depth: SD; Soil Organic carbon: SOC.

The numerical values that are contained in Table 4.14 reflect the pairwise comparisons made between the criteria. Each digit depicts the relative importance or preference of one criterion when compared to another. The values have been normalized within each row to ensure that they sum up to 1 and span from 0 to 1. The comparisons were conducted on a ratio scale whereby digits that are in proximity to 1 indicate a stronger preference or higher importance, while those that are in proximity to 0 convey a weaker preference or lower importance. The final column in Table 4.14 provides the weights that have been assigned to each criterion. These weights denote the relative importance of each criterion in the decision-making process for the establishment of grazing reserves. They were derived from the pairwise comparisons and represent the overall priority of each criterion.The level of consistency (CR) was computed as 0.053 and, as it is below 0.1 (10%), it was deemed satisfactory.

In addition, Table 4.14 indicates that the criterion carrying the greatest weightage is Land use and Land Cover, with a weight of 0.22. This implies that the evaluation process for the siting of grazing reserves in the study area accords utmost importance to land use and land cover amongst the factors under consideration. The criteria that hold relatively high weights are distance from water (0.16) and distance from settlements (0.13), signifying theircrucial significance in the assessment process. Conversely, the remaining criteria, namely slope, distance from road, soil pH, rainfall, temperature, elevation, soil depth, and soil organic carbon, bear lower weights ranging from 0.06 to 0.04, thus indicating their relatively lower significance in comparison to the criteria carrying higher weightages.

4.5 Land Suitability Map for Grazing Reserves in the Study Area

Having considered all the criteria in the study area, a suitability map of Zuru Emirate was produced as shown in Figure 4.13.

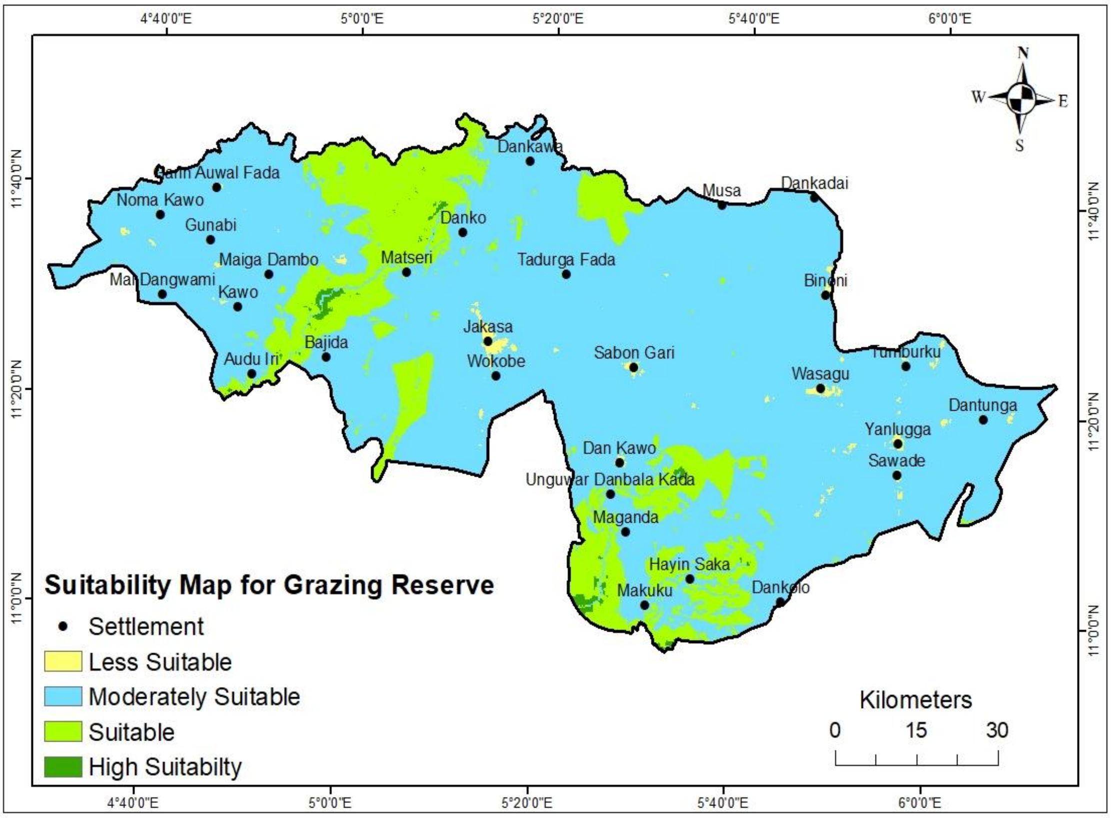

Figure 4.13 Land Suitability map for grazing reserve in Zuru Emirate

The statistics obtained from suitability map (Table 4.15) shows four levels of suitability; less suitable, moderately suitable, suitable, and highly suitable areas.

Table 4.15 Land suitability map for grazing reserves in Zuru Emirate

Level of Suitability	Area (sq.km)	%
Less Suitable	58.59	0.66
Moderately Suitable	7192.83	81.34
Suitable	1552.66	17.56
Highly Suitable	38.96	0.44
Total	8843.04	100

The land area classified as less suitable, comprising 58.59sq.km, constitutes a mere 0.66% of the total land area. This implies that the proportion of the total area deemed to have low suitability for grazing reserve establishment is relatively small. These areas can be found in Wasagu, Jakasa, Yanlugga and Sabon Gari, amongst others. This result is similar with the findings of Rouhi-Moghaddam *et al.* (2017) who conducted a similar study of Bagheran Birjand watershed, South Khorasan province, Iran and discovered that 6.21% of the area was less suitable for siting rangeland. This result is also consistent with the report of Ayoubi and Alizadeh (2006). Qualitative analysis of land suitability for livestock grazing in Mehr Catchment in Sabzevar, Khorasan, Iran. who applied GIS, AHP, and weighted overlay analysis to produce a suitability map for livestock grazingand revealed that 14% and 11% of the land was less suitable for grazing.

Moreover, the moderately suitable category encompasses a significantly larger expanse, amounting to 7192.83sq.km, which accounts for 81.34% of the total area. This clearly demonstrates that there is a significant portion of the region that is moderately suitable. Land areas that possess moderate suitability are situated in Gunabi, Dankawo, Noma, Kawo, Dankadai, and other settlements. This result is in line with the report of Akomolafe (2015) who conducted land suitability analysis for siting grazing reserve in Kaduna and Niger State and found out that 62% of the study area was moderately suitable for siting grazing reserve. On the other hand, the result is contrary to the findings of Emenike *et al*. (2016) who determined and map suitable rangelands for livestock grazing in Irepodun area of Osun state and found that only 15% of the study area was moderately suitable for livestock grazing. In contrast, the suitable category covers an area of 1552.66sq.km, representing a relatively smaller portion of 17.56% of the total area. Within the Emirate, suitable areas are situated in Matseri, Hayin Saka, Unguwar Danbala, and other similar locations. This suggests that the land area suitable for establishing grazing reserve is comparatively limited.Lastly, the highly suitable category encompasses the smallest area, with only 40.84sq.km, representing a mere 0.44% of the total area. Thus, it can be inferred that the proportion of the land area that is exceptionally highly suitable for grazing reserve establishment is very limited. Highly suitable areas can be found in the vicinities adjacent to Maiga Dambo, Bajida, Danko, and Makuku.

The production of a land suitability map constitutes a highly valuable source of information for decision-making processes related to the establishment of grazing reserves in Zuru Emirate, Kebbi State. Such information is useful in guiding authorities, managers of land, and stakeholders in their endeavour to identify areas that are appropriate for grazing activities, while also making sure that resources are allocated in an effective manner, and that the utilization of land for grazing purposes is sustainable.

4.6 Reliability of Land Suitability Map for Siting Grazing Reserves in Zuru Emirate

It is noteworthy that NDVI is a widely used index in remote sensing and vegetation studies that provides insights into the health and density of vegetation in a given area.

In order to assess the reliability of the suitability map produced in this study, the Normalized Difference Vegetation Index NDVI method was employed. The zonal statistics tool in the spatial analyst extension in ArcGIS 10.8 was used to calculate the mean (NDVI) value of each land suitability class as presented in Table 4.16.

Table 4.16 Mean NDVI value of land suitability class

Level of Suitability	**Mean**
Less Suitable	0.4114

Moderately Suitable	0.4978
Suitable	0.5055
highly Suitable	0.5057

Based on the findings presented in Table 4.16, it is evident that the highly suitable class exhibits the highest mean NDVI value of 0.5125. This observation is indicative of the presence of a dense and healthy vegetation cover as shown in Figure 4.14 reliability of land suitability map 0.788958. Similarly, the mean NDVI value of the suitable category is 0.5067, which signifies a relatively good vegetation cover that can support grazing activities. The moderately suitable class has a mean NDVI value of 0.4974, suggesting a slightly better vegetation cover. In contrast, the less suitable category has a mean NDVI value of 0.3747, indicating relatively low vegetation density. These outcomes corroborate the accuracy of the land suitability map, as the results of the zonal statistics analysis validate that the highly suitable class has the highest mean NDVI value of 0.5125, whereas the low suitable class has the lowest NDVI value of 0.3747.

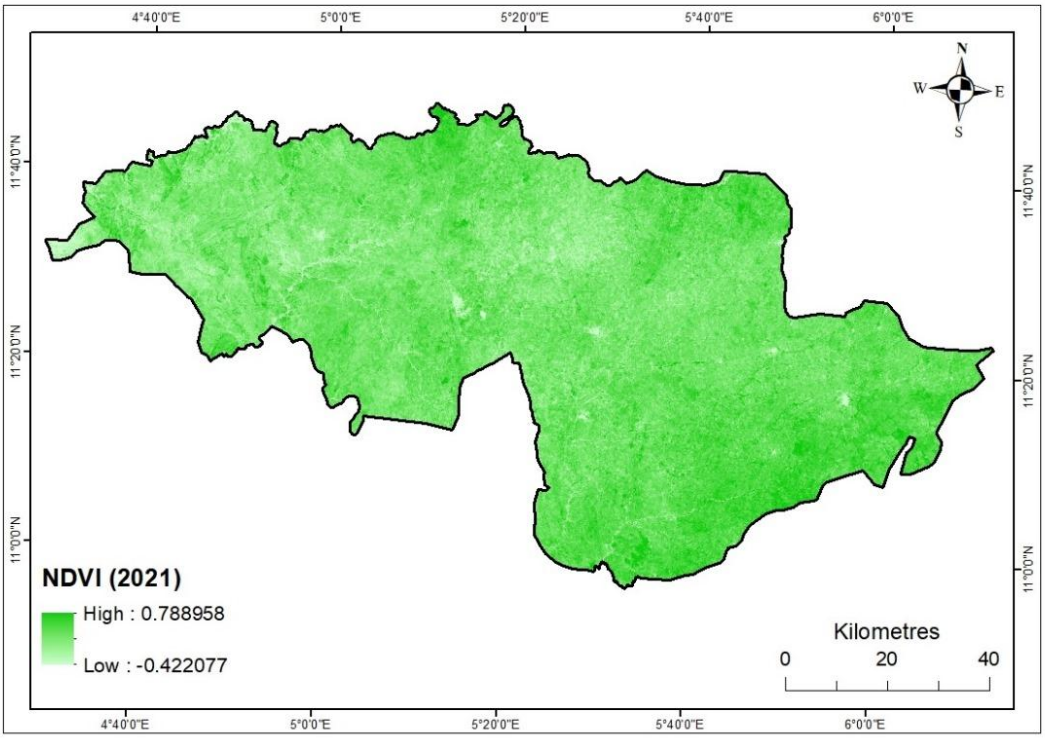

Figure 4.14 Reliabilityof land suitability map for siting grazing reserves in Zuru Emirate.

From figure 4.14. The reliability of the land suitability map shows high-density values of 0.788958, indicating a dense and healthy vegetation cover suitable for grazing activities, while a low value of -0.422077 indicates a relatively low vegetation density.

4.6 Impact of the Study and Remediation

Conflicts between herdsmen and farmers have arisen due to cattle herds destroying farm lands. Despite government efforts to address these issues, there is a strong need for pastoralists to be granted rights to land with basic amenities for their herds and families, despite the destruction caused by cattle herds. This study furthermore shows and determines the kind and rate of the limitations and factors reducing the suitability of a particular area for siting grazing reserve.

The use of Multicriteria Analysis (MCA) in GIS can help address the issue of farmer-herder conflicts by identifying suitable sites for nomad settlements year-round, away from agricultural lands and human settlements. This ensures the security of lives and property, and boosts livestock production, positively impacting socio-economic development. The study can also serve as a benchmark for land or site suitability analysis for grazing reserves in other states, providing a model for improvement.

CHAPTER FIVE

SUMMARY, CONCLUSION AND RECOMMENDATIONS

5.1 Summary of Findings

This research used geospatial techniques and multicriteria decision analysis (MCDA) tools to analyse land suitability for siting grazing reserves in Zuru Emirate, Kebbi State. Based on this study, the following findings have been obtained:

i. Zuru Emirate is predominantly covered by bareland, comprising 91.09% of the entire emirate. Farmland (5.62%), vegetation (2.62%), built up (0.58%), and water body (0.09%). It isindicative that the presence of vegetation cover, the area can support grazing activities.

ii. Based on the findings from the AHP weighted analysis of the criteria, it revealed that land use land cover was the most influential criterion with a weight of 0.22 (22%), while soil depth and soil pH had the lowest weight of 0.04 (4%).

iii. The results of land suitability map for grazing reserves indicated that 0.92% of the study area is less suitable, 83.13% is moderately suitable, 16.48% is suitable, and only 0.46% of the study area is highly suitable for siting grazing reserves.

5.2 Conclusion

This research used geospatial and AHP techniques to assess land suitability for establishing grazing reserves in Zuru Emirate. Based on the findings of this research, it can be concluded that land use and land cover are important criteria for land suitability analysis in the study area. In addition, based on the land suitability mapping, it can be concluded that Zuru Emirate, Kebbi State is moderately suitable for siting grazing reserves.

In conclusion, these findings collectively contribute to knowledge by providing a comprehensive assessment of land use patterns, criteria influencing land use decisions, and the suitability of the landscape for siting grazing reserves. The integration of remote sensing data, GIS techniques, and analytical methods like AHP enhances the strength of the study, yielding valuable insights for sustainable land management and decision-making in the study area.

5.3 Recommendations

Based on the findings of this research, there is urgent need to reform and improve grazing arrangements. It follows that the Government should therefore continue with its policy to develop existing grazing reserve land in order that more areas be opened for improved livestock production and then, the lingering crises between farmers and pastoralists can be curtailed or eliminated. Besides, grazing reserves development to a large extent will bring about positive changes in the socio-economic well-being of farmers in rural areas and for this reason too, this objective should be further pursued. In this context, it is equally important to ensure that all existing grazing reserves should only be utilized for livestock purposes, including those that may be privatized. Other important recommendations emanating from this study are enumerated below:

i. Given that the research has recognized land use and land cover as the most significant factor for land suitability analysis, it is recommended for Kebbi State government,the four local government areas in Zuru Emirateand interested parties to assign importance to efficient land use and land cover management.

ii. Kebbi State government should liaise with the Federal government through theOffice of the Surveyor General of the Federation (OSGOF) and other stake holders in Surveying profession to jointly survey, demarcate and officially document existing grazing reserves and stock routes that have not been over-run by human settlements and infrastructure to curtail further conflicts between farmers and herders.

iii. As a matter of urgency, it is recommended that a comprehensive study be carried out in each state of the federation to actualize the suitable areas for establishing grazing reserves and assess how it can contribute to an integrated programme of development according to the local circumstances and in relation to an overall national plan.

iv. New Grazing reserves and stock routes in consenting states should be established and livestock production and management be improved in order to minimize contacts and friction between herders and farmers.

v. It is recommended that consistent monitoring and revisions of the land suitability map be conducted to allow decision-makers to make informed decisions about sustainable land use planning and management.

vi. This study can be further extended to develop a model that can be used continually with additional criteria for greater efficiency of the geospatial method adopted for suitability mapping of grazing reserves and routes.

5.4 Contribution to Knowledge

The following are the contributions to knowledge:

i. The discovery that 91.09% of the study area is covered by bareland serves as a crucial foundation for comprehending the current land use pattern in the study area. The dominance of bareland indicates potential challenges regarding soil erosion, desertification, and other ecological problems that could impact the overall health of the ecosystem. The distribution of different land cover types, such as farmland, vegetation, built-up areas, and water body, offers valuable insights into the composition of the existing landscape.

ii. The finding that land use land cover carries the highest weight (22%) among the criteria signifies its paramount importance in decision-making processes related to land management (in this case, the establishment ofgrazing reserves). Understanding the relative influence of criteria like soil depth and soil pH (with the lowest weight of 4%) is crucial for making informed decisions in land use planning.

iii. The identification of land suitability for grazing reserves provides actionable information for resource management. The realization that only 0.46% of the study area is highly suitable for siting grazing reserves emphasises the need for careful considerations when establishing such reserves. The distribution of suitability classes (less suitable, moderately suitable, and suitable) allows for targeted interventions and planning strategies based on the specific characteristics of each area.

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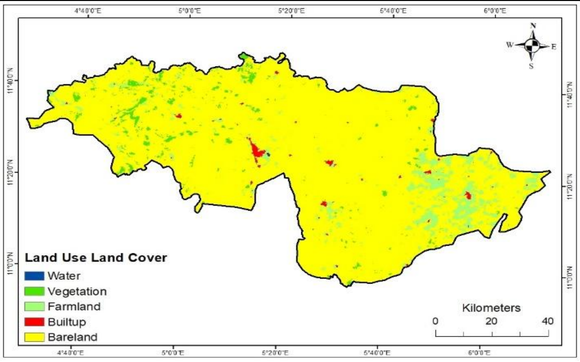
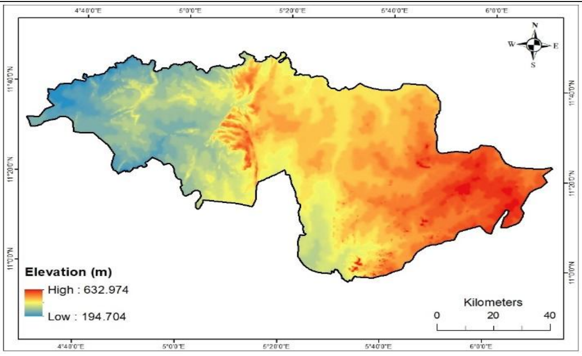
APPENDICES

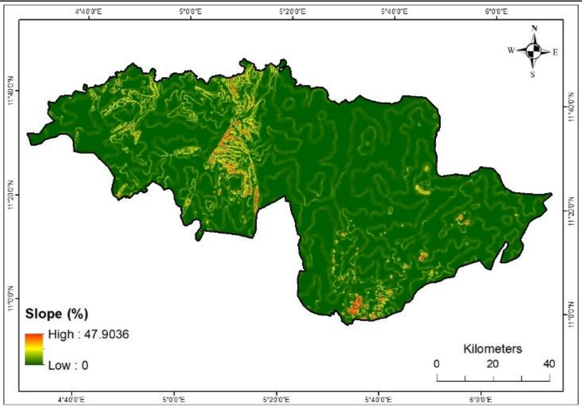
Appendix I Criteria Maps



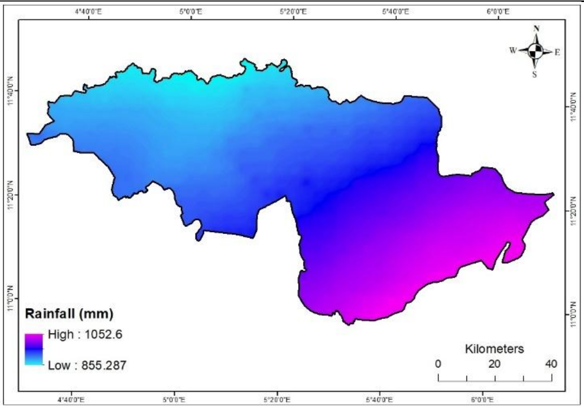
Land Use Land Cover Map of the Study Area



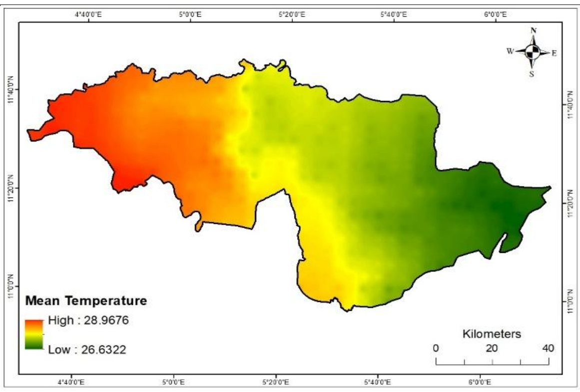
Elevation Map of the Study Area



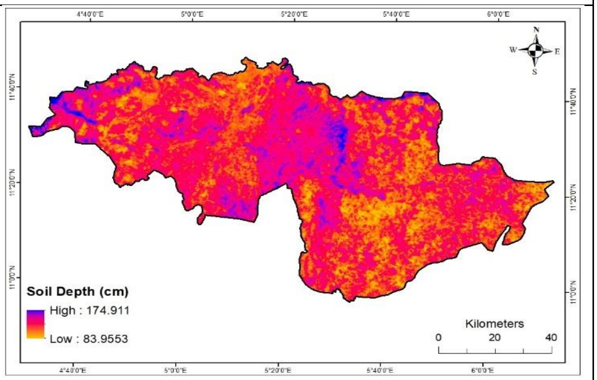
Slope Map of the Study Area



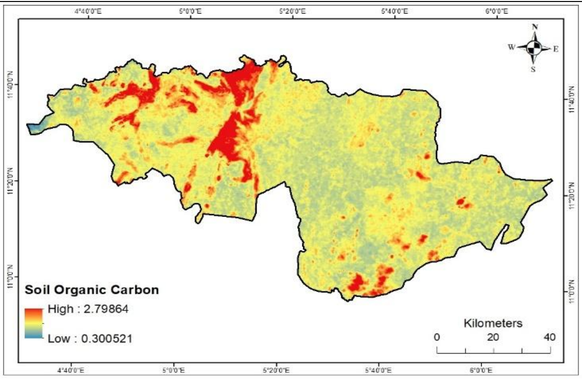
Rainfall Map of the Study Area



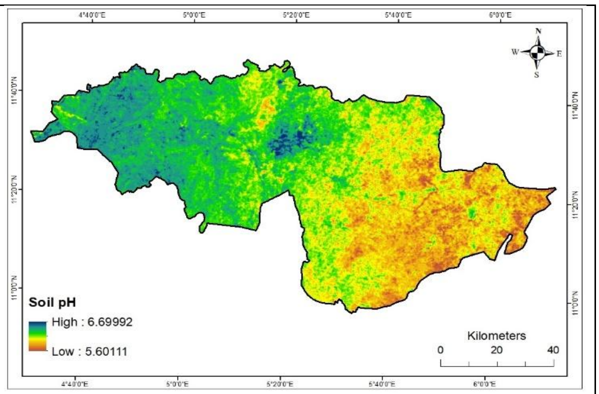
Temperature Map of the Study Area



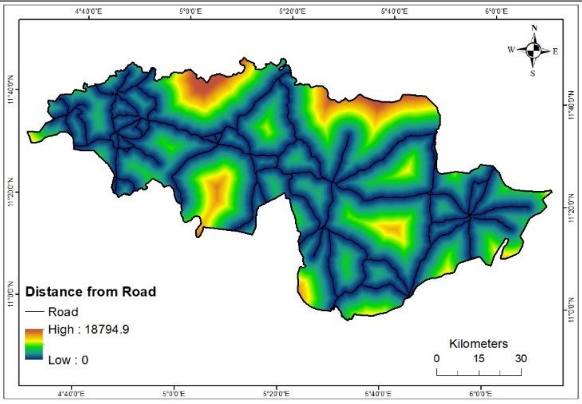
Soil Depth Map of the Study Area



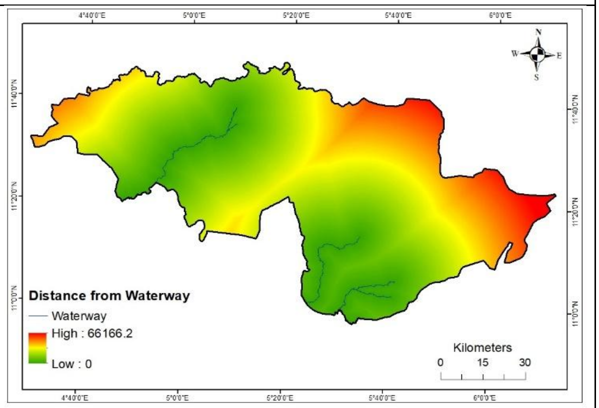
Soil Organic Carbon Map of the Study Area



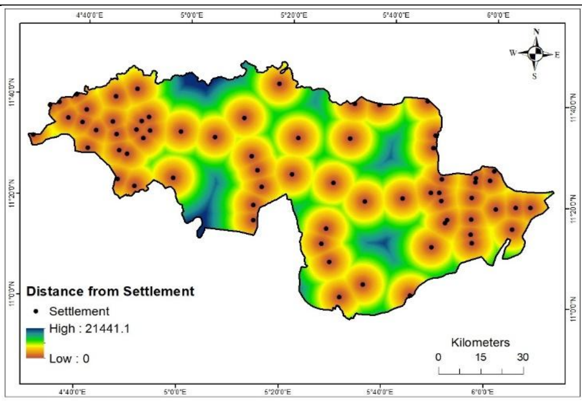
Soil pH Map of the Study Area



Distance from Road Map of the Study Area



Distance from Waterway Map of the Study Area



Distance from Settlement Map of the Study Area